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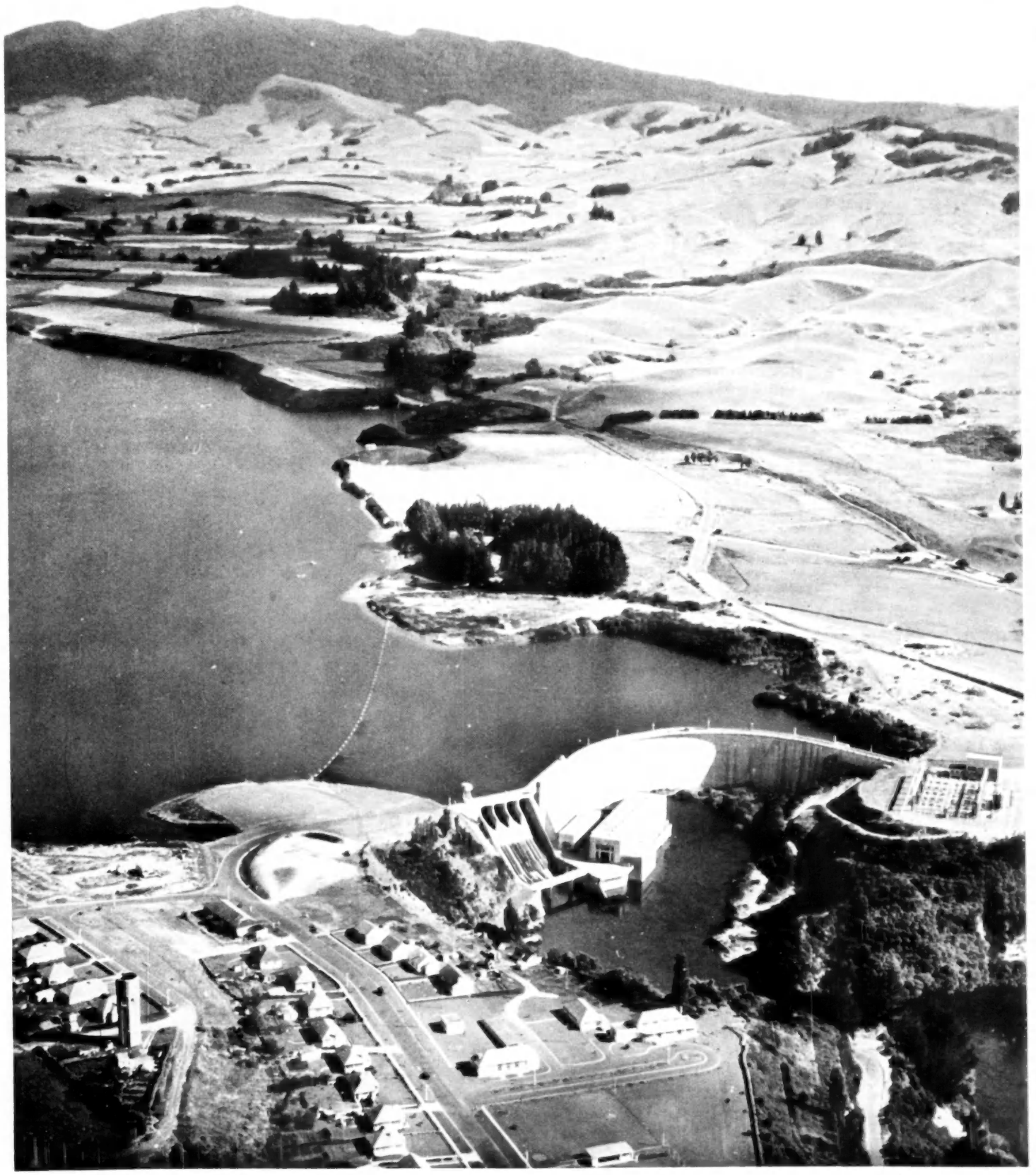

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LOOKING AT SHIPS

ENGINEERING designers can be artists if they choose. Whether the design is simple or complex, there is invariably some freedom of form even after fulfilling all functional requirements. If the design is one that must face public scrutiny—of a ship, a motor-car, or a transmission tower, for example—then the designer is compelled to give full consideration to aesthetic factors. Naval architects gave some thought to this aspect of their work last week when Mr. Laurence Dunn presented a paper on the subject at the Institution's Bristol summer meeting. " From the time of her maiden voyage," he said, " the ocean-going ship is subject to international scrutiny. Her appearance is no longer judged through local eyes, by local shipyard or home port standards. Instead, she is judged by persons abroad who may have no particular bias towards things British and who compare her with contemporary products of other nations who have a flair for creating well-proportioned and elegant ships."

Mr. Dunn has made a serious attempt to discover why some ships are visually unsatisfying and how, with slight modifications, they could be made more pleasing. His enthusiastic attempts to improve design are well timed, but can he hope to convert naval architects with suggestions that one kind of detail looks better than another? Visual design goes deeper. Lack of ability in it stems from a fundamental gap in a naval architect's training. A suggestion that one type of curve looks happier than another could, unless the recipient is taken right back to basic principles, lead to yet further bad designs. Such comparisons are meaningless unless we relate the detail to the whole shape. Mr. Dunn's acceptance of the amount of soft contours now in vogue—" in these days when ships are given more and more curves . . ."—is itself an alarming premise. It is an acceptance of the shapes to which our sensibilities are being schooled by car-body design. Car bodies are pressings, leading naturally and inevitably to soft shapes, which are acceptable to the eye by the sheer habit of seeing them, and they are conceived as one unit without superstructure. But a ship is not pressed; it is more akin to a building than to a car. A bulbous structure mounted on a deck would be as aesthetically satisfying as a car body on the roof of a building.

The same visual rules hold for ship design as for building architecture. In both, the holding together visually of large shapes is the problem. To achieve this we must examine the method by which shapes are transmitted by the eye to the mind. The eye sees shape only by its point of turn from one face to another. If we look at a building in silhouette we are unable to see its three-dimensional shape. It is only when the light comes round far enough to register the point of turn, by a hard line at a sharp edge and by tonal change in the case of a radius, that the shape becomes discernible. If then, our eye depends on the point of turn to understand the shape, it is essential that our eye is not led off the shape by breaks in this turning point. A good architect designing a building recognises the necessity for a continuous arris (i.e., turning point or edge) so that the eye may travel quickly enough over so large a shape for it to be comprehended as one entity. This factor is sometimes overlooked in naval architecture. Instead of the whole ship being conceived as one unit with a continuity of arris, bits of superstructure are superimposed, giving the same effect as a building with a number of lean-to additions.

In the days of sail the very complexity of the rigging formed a visual web of unity. The ship was seen not as a solid but as a structure. She was not designed to look well but to sail well and every bit of equipment on her was necessary and functional. But with engine power, less is on show; and the less there is to see, the greater the necessity to send the spectator's eye quickly over the whole vessel by clear-cut architectural devices rather than by numerous small curves. Unless we are to design ships as great sleek curved shapes like vast aircraft fuselages, with no extraneous bits and pieces showing, there will continue to be many straight lines in the design. But since a ship is already endowed with a generous share of both horizontal and vertical curves in its hull shape, any further curves in either plane used on deck structures must be used with the utmost economy and caution. Mr. Dunn's suggestions that additional curves may improve the effect could easily lead, in the hands of a ship designer with less keen sensibilities than his own, to the bubble effect that we see in many Continental ships. If a bridge or funnel looks stark and insular it is far more likely to be due to bad proportion than to lack of curves.

No amount of surface decoration or the addition of radii or angles can improve bad proportion. When we say " Now there's a pretty ship " it is not usually these decorations which catch our eye but the unity and completeness of its overall proportions. Little need be said about dummy structures: cowlings, fairings and the dummy masking of shapes may be all right on luxury liners where it is desired to give the impression to passengers that everything about the ship is solely for their enjoyment, and that nothing is

functional, but this phase has, fortunately, come and gone. British designers are again facing the reality of clean, functional ships of good proportion and without the frills and pseudo contemporary additions that are sadly apparent in many of the ships of other countries.

* * *

Plain Words

One of the absurdities of our time is the growth of "do-it-yourself." The benefits of the division of labour, built up over hundreds of years of industrial development, are thrown away in a craze for amateur decorating, building and repairing.

It is more than a craze. It has come to stay, because it is a product of economic and social tendencies that are not likely to be reversed overnight. Through their trade unions, men press for shorter working hours. But they have no very clear conception of worthwhile uses to which they will put their ample spare time. Through their political parties, men are given the social welfare which buys their votes. But they are only dimly aware of the burden of taxation which they are creating for themselves. The resultant of these two forces—shorter working hours and increased taxation—is less personal choice in the spending of one's own money. For the middle classes particularly, after all the more or less essential things have been paid for, there is precious little left to spend as you will. So as much as half, if not more, of the interior decorating work of this country is done by householders and their families. People make their own furniture from kits of parts, and they do as much repair and maintenance at home as they can fit in. The crowning irony is a man working overtime in his own home—sometimes till the early hours of the morning—with his wife taking the part of a very demanding progress officer.

It is no use saying that the do-it-yourself movement is good because it encourages men to take pleasure in making things and doing jobs for themselves. If that were the whole story the movement would be wholly acceptable. But it is not. What is happening is that a considerable amount of work is being done reluctantly by inefficient amateurs. Nor is it relevant to say that labour costs for decorating, etc., have gone up; all labour costs have, and thus all wages are much higher than they were before the war. It would be better for the country and for the individual if men were to work at their own jobs for slightly longer hours, thereby earning enough money to pay professionals to carry out repair and maintenance.

By all means let men paint walls, if they like painting walls; let them hang wallpaper, if they enjoy hanging wallpaper; let them make furniture, if the smell of sawn timber is a savoury smell in their nostrils; let them lay bricks, if they want to emulate Sir Winston Churchill. But let us end this confusion between true hobbies and desperate attempts to make ends meet. We shall all be better off if we do.

TOOLS FOR BUSINESS

The recent Business Efficiency Exhibition at Olympia was largely a display of office equipment. This was justifiable since the efficiency of a business depends on the efficiency of its office staff. The analysis, and communication, of information is their concern. Any firm must know how it stands as regards market demands, rate of production, costs, etc., if it is to remain competitive.

The exhibition was the biggest of its kind to be staged in this country. Some 130 firms displayed equipment on stands that covered an area of 3½ acres. Most noticeable was the feeling that an office revolution was about to take place. Alongside conventional filing cabinets, ledgers, wrapping machines, were displayed electronic computers and other equipment capable of being built into a comprehensive data processing system. Equipment designed to improve the working conditions of office staff was shown close to equipment that could replace large numbers of such staff. The exhibition was of interest to the small firm anxious to improve the efficiency of its staff and to the large firm contemplating a programme of automation.

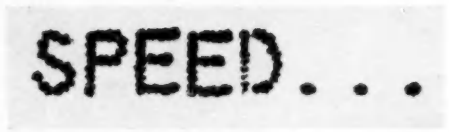

Fig. 1 This enlarged example of high-speed "printing" was produced at a speed corresponding to 42,000 characters a minute.

The office equipment industry, which the exhibition represents, has been expanding rapidly since the war. In 1939, output was £2½ million; in 1956, output was over £65 million, of which £25 million were exports. This year further increases in exports have occurred, the largest being in the shipments to the United States, which rose by about 50 per cent. in the first three months of the year.

COMMUNICATIONS

A wide variety of modes of communication is available to business. The typed letter is still a favourite and it seems unlikely that any machine will be found to replace the shorthand typist. Typewriters and their accessories formed a prominent part of the exhibition.

An office composing machine was exhibited by Vari-Typer Limited, 210 Euston-road, London, N.W.1. It has a conventional typewriter keyboard but produces copy with a "professional typeset" appearance. A wide range of type fonts is available. Two type fonts fit into the machine at one time; each font is a complete unit and bears ninety characters. The fonts are made of a hard light alloy and each covers half the surface of a narrow drum. The normal writing line is 15·1 in. but if automatic evening of the right-hand margin is required the maximum line length is 7½ in.

When typewriters are used to fill in forms with a large number of columns, it is normal to use a tabulator key. By pressing the key the typewriter carriage moves across until it comes to a preset stop, or tab. Initially the tabs are set up by hand at positions corresponding to the columns. With complicated forms the labour saving gained can be lost if the tabs have to be reset very often to accommodate varying columns. Electronic tabulation, displayed by IBM United Kingdom Limited, cuts out the unproductive tab setting time. It uses forms on which the tabular positions are printed in electrically sensitive ink. When the tabulator key is pressed the typewriter reads the form electronically and the carriage automatically spaces to the next typing position.

An alternative to producing copies with carbon paper is offered by the Robotyper produced by Royal Typewriters, 36 Worship-street, London, E.C.2. The machine is primarily not a typewriter but is attached to one or more electric typewriters which are controlled by it. Its principle of operation is similar to that of the pianola. A perforated record roll passes over holes in a tracker bar; when a hole in the role coincides with a hole in the bar a rise of pressure occurs in a Polythene vacuum line, and the appropriate key is operated. It is possible for the bulk of a letter to be typed automatically at high speed, and the address and salutation to be typed in manually. As a result each letter looks like an individual copy.

An alternative to the typed letter was offered by the National Telewriter (1955), Limited, Northwood Hills, Middlesex. Their telewriter makes "handwritten messages deliver themselves as you write." The transmitter has a pen mounted on a pantograph. When the operator uses the pen to write a message, the arms of the pantograph generate electrical signals. The signals are fed by wire to the receiver, where they actuate a second pen which reproduces the written message. A selector panel directs the message to the department of works for which it is intended.

Teleprinter systems were also demonstrated. The model 75 teleprinter displayed by Creed and Company Limited, Croydon, can operate at 100 words per minute. It is available as a transmitter-receiver or as a receiver only. A re-perforating attachment can record incoming messages on standard five-unit punched tape—giving a convenient record.

A revolutionary way of printing was exhibited by Powers-Samas Accounting Machines (Sales) Limited, Holborn Bars, London, E.C.1. The speed of printing is 42,000 characters a minute. In this time 140 styli, arranged in a bank 14 in. wide, print 300 lines. As shown in Fig. 2 each stylus moves in a zig-zag across the space required for one character. Electric pulses activate the stylus and cause it to print dots at certain points of its travel. Programming the electrical pulses so that they produce the sequence of dots necessary to form a given letter, is done by rotating discs with metal inserts, Fig. 3. The sequence with which the inserts pass a detecting head determines the sequence of the dots. There are 50 discs. Each disc can cause its own character to be formed by any number of styli in each line of printing.

The high-speed printer is actually embodied in a Samastronic Tabulator. Information is fed into the machine on punched cards and after the required arithmetic operations are performed the results are printed. Each card passes two sensing stations. At the first, sensing occurs of the holes that describe the operations to be

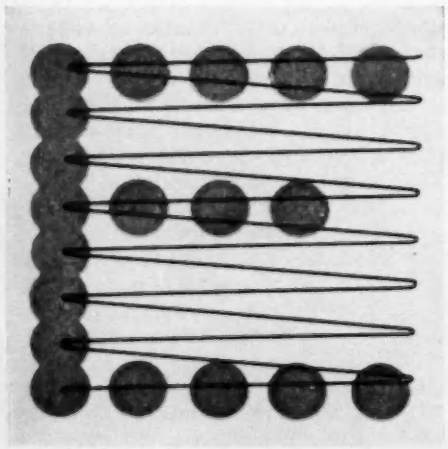

Fig. 2 The stylus of the Samastronic printer follows a zig-zag path. Electrical pulses to the stylus cause it to make a series of dots in the sequence that defines a letter.

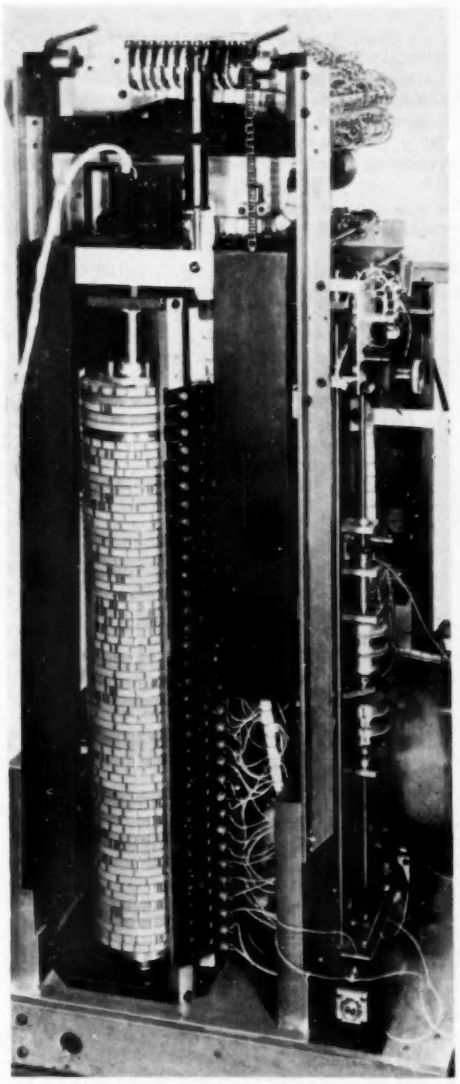

Fig. 3 The electrical pulses that produce each of the 50 characters are derived from 50 rotating drums. Metal segments of the drums provide the correct sequence of pulses.

performed. At the second, information is extracted from the card and the various processes initiated. The character spacing of the printing at the output is that commonly used in typewriters, namely ten characters to the inch. Character height is determined by the speed at which the paper is fed.

RECORDS

Speech recording machines are finding greater use. A dictation by telephone system was displayed by M. and L. Haycraft Limited, St. Stephen's House, Westminster, London, S.W.1. It is called the Agavox Telediction System. Each person dictating has a telephone on which there are several push buttons. These control the dictating machine, which is in the typing pool. The user can record, play back, and make corrections.

He has a selector switch that finds a free machine for him, and if he wishes to speak to the typing pool supervisor, there is a button to call her. A warning noise indicates the approach of the end of a record. Automatic control units in the typing pool carry out the instructions of the dictator. For example, when he presses his " end of letter " button, the unit causes a pin hole to be punched in the paper index strip on the recorder. When the typist gets the index strip she can see from the pin holes how many letters have been dictated, how long each is, and the position of any corrections. It is important when a battery of dictating machines is installed that the dictators organise their work to keep the machines in constant use.

A similar system was shown by E.M.I. Sales and Service Limited, Hayes, Middlesex. Called the Emidicta Network, it embodies automatic hunting. This technique ensures that when the end of a disc is reached, the dictator is automatically switched to a vacant machine at the central exchange. He does not have to manipulate the switches himself to hunt for another machine. The same company displayed a pocket recorder weighing about 2 lb. It contains an unspillable accumulator battery to power the motor. An associated transformer and rectifier enables the battery to be recharged from alternating current mains. A kit has been developed which enables a Minifon to be fitted into a car (Fig. 5).

On the stand of the Dictaphone Company, Limited, 17–19 Stratford-place, London, W.1, a four-channel magnetic Dicta-tape recording machine was shown. It has been designed for heavy duty communications logging, recording up to four channels on one tape simultaneously. It operates for eight hours without a change of reels. Alternatively it can be modified to run 24 hours without changing reels.

Several ingenious means of locating personnel were exhibited. The Audio Frequency Staff Location System, whereby anyone needing to be on call carries a fountain pen receiver clipped in a pocket, was shown by Siemens Brothers and Company, Limited, West Kensington, London, W.14. This system of paging works on the magnetic induction principle. A single loop of wire around a building carries audio frequency signals from a 70 watt amplifier. The magnetic field so generated is picked up by the fountain pen receiver. When a paging signal is transmitted, the person alerted presses the pen clip and places the instrument near his ear. The message can then be heard.

Staff location by lights that flash the number of the person required was also shown. A system displayed by IBM United Kingdom Limited, 101 Wigmore-street, London, W.1, used the numbers on a clock dial. Normally the figures appear black, but when a particular member of staff is required his number on the clock face glows red.

The automatic office was the theme of the stand of Leo Computers, Limited, Brook Green London, W.6. It was impractical to show Leo itself on the stand, since it is not one electronic machine but a whole series of machines linked together. Consequently the stand formed an information theatre where films and lectures explained the working of the automatic office and its applications.

The British Tabulating Machine Company, Limited, 17 Park-lane, London, W.1, displayed their new Hec type 1201—a general-purpose electronic computer. The computer has a punched card input. Punched cards and printed outputs are possible. One of these machines is installed in the offices of the Morgan Crucible Company, Limited, and another is about to be installed in the Western Region Headquarters of British Railways. The firm displayed a variety of punched card equipment including a new tabulator—type 906—that has an operating speed of 200 cards a minute.

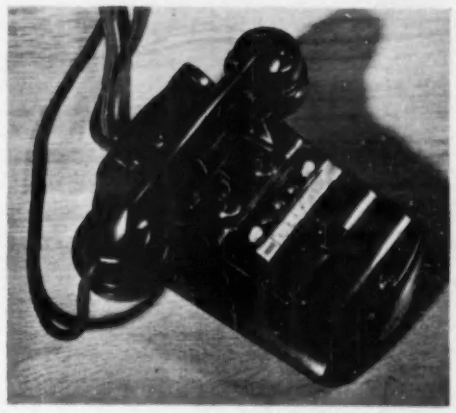

Fig. 4 With the Telediction system an executive can pick up his telephone and dictate to a recorder. Buttons on the telephone enable him to record, play back, and make corrections.

Fig. 5 The Minifon is a miniature wire recorder that can fit into the pocket. Here it is shown installed in a car.

Fig. 6 A new general purpose computer, the Hec type 1201, operates from punched cards.

SUMMER MEETINGS

The professional engineering institutions and societies traditionally fill the void between one winter's session of technical meetings and the next by holding a special summer meeting. Four which have been held in recent weeks have taken members to Cambridge, Manchester, Newcastle, and (for the "Juniors") to Switzerland.

I.Mech.E. at Cambridge

A BREADTH OF ENGINEERING

The view that "all engineering is one" has long informed the education of engineers in Cambridge. A broad training without undue sacrifice of depth has been the aim of the University engineering department since its foundation, and in spite of increased specialist demands, this character has persisted.

Few would doubt the value of such a training, and Cambridge engineers have, as Sir George Nelson, President of the Institution of Mechanical Engineers remarked at the opening of the Institution's summer meeting last week, brought not only greatness to the profession but benefits to the world in general. In choosing Cambridge as the venue for their meeting, the Institution had naturally taken education as its principal theme, and both addresses delivered on that occasion were concerned broadly with this topic—one with the history and character of engineering education in Cambridge and the other with some of its products. Professor J. F. Baker, O.B.E., F.R.S., spoke on "Engineering Education at Cambridge," and Mr. G. B. R. Feilden on "Some Contributions of Cambridge Men to Mechanical Engineering."

FUNDAMENTALS FIRST

Cambridge engineering education has always been founded on the thesis that an engineer must first have a thorough grounding in the fundamentals of mathematics and physics, with a useful working knowledge of chemistry and metallurgy. Possibly the clearest statement of this idea was that made 26 years ago by Sir Charles Inglis, Professor Baker's great predecessor as head of the Cambridge engineering department. He said: "We aim at giving our students the broad general principles which underlie all the main departments of engineering rather than an intensive training in any one particular branch. The honours course extends over three years, and it is only in their third year that students are permitted to specialise, and then only to a limited extent. In their Tripos they are tested as to their knowledge over a wide range of subjects, and no options are permitted whereby this test of basic knowledge can be made less comprehensive. As the result of this broad training we do not claim to mould our students into full-fledged engineers, but we do claim that they acquire a working knowledge of the fundamental principles underlying all branches of engineeering—structural, mechanical and electrical."

This system holds broadly to-day, though now it is possible to proceed to an honours degree following a full three years of non-specialised study; and more able students take the same examination, Part I of the Tripos—after two years and prepare for a specialised Part II in their third year. There is also a third course open: for those less mathematically minded a pass degree can be obtained in Engineering Studies, which provides a general engineering groundwork in the first two years with a third year devoted to some special field plus two obligatory subjects—drawing, and industrial administration and economics.

Though not the first Cambridge man to make a contribution to engineering science (Phineas Pett, who joined Emmanual College shortly after its foundation in 1584, became the first Master Shipwright), Isaac Newton's was probably the most profound. His discovery of the "infinitesimal calculus" and his later work on the laws of motion and gravitation provided that broad intellectual foundation for which Cambridge engineering has since become celebrated, and on which the subsequent development of analytical engineering in all its branches has been based. The study of engineering as such in Cambridge strictly dates from 1796 when the Jacksonian Chair of Natural Philosophy was established; thereafter lecture courses were available which covered comprehensively, if rather descriptively, engineering in all its branches.

A special syndicate recommended in 1875 that "there shall be established in the University a Professorship of Mechanism and Applied Mechanics . . . to teach . . . (1) The Principles of Mechanism, (2) The Theory of Structures, (3) The Theory of Machines, (4) The Steam Engine and other Prime Movers . . . Stipend £300 per annum." Objections were raised on several grounds including the choice of the title "Applied Mechanics," since no doubt there would soon be a call for a further chair, this time in "Engineering" itself.

THE DESERTS OF GENIUS

Robert Phelps, of Sidney Sussex College, hotly opposed the third engineering professorship to be proposed, for reasons which might find sympathy—at least among engineers and engineering lecturers—to-day. He wrote: "As to the question of a real Professor of Mechanism and Engineering, that is, of a Professor endowed with the special genius and whose function would be that of original research. Well, Sir, I really think that I need only express my amazement that any sensible man can be so weak as to believe that, in these days, when the possession of anything like such genius would ensure to its distinguished possessor an enormous fortune in any country in the world, the offer of £500—or even of £5,000—a year would induce such a man to give his undivided attention and energies to the real interests of these truly important Departments in the University." The chair, was, however, established and James Stuart, a mathematician, became the first professor in 1875. In view of his theoretical training, it is perhaps curious that he tended to overstress the need for practical workshop training as against the teaching of fundamental science.

Sir Alfred Ewing restored the proper balance, and he it was who, in 1892, secured the establishment of the Mechanical Sciences Tripos—that is an honours course of study—and laid down the general principles described in the statement by Sir Charles Inglis quoted above. A further step away from the practical was made by Bertram Hopkinson, who said that if there was to be a science of engineering at all, it must be the very embodiment of a union between mathematics and physics. Practical engineering was to appear only in so far as it provided suitable scientific problems. This is largely the position to-day.

FEWER FACTS

Thus engineering education in Cambridge combines a broad view of the entire engineering field with a sound knowledge of fundamentals; but there is something more. A new dimension is given to education through the college system, whereby contacts may be made with students in any number of alien fields. Unfortunately, whereas in the middle years of the last century our forbears ranked engineering equally with the other modern subjects worthy of university study, there are nowadays those who mistrust engineering education as being technical and vocational. In fact, as Professor Baker pointed out, "men reading for the Mechanical Sciences Tripos are expected to memorise fewer facts than those in any other faculty with the exception of mathematics."

Teaching so broad a subject clearly has problems of its own, mainly because staff should have industrial experience and are therefore likely to have specialist interests of their own. The specialist Part II of the Tripos was established partly in the interests of the staff, who would consequently be able to exercise their pioneering zeal in teaching some of the latest advances in engineering. Paradoxically this assists in eliminating any tendency to introduce specialist elements into the general courses. Similarly, although research is an important part of university life, it is regarded as subordinate and contributing to undergraduate teaching. The emphasis on teaching also makes it undesirable for university staffs to engage in routine design or so-called consulting work, but it should be borne in mind that a member of staff engaged on research work is necessarily forced into contact with industry and soon becomes such an authority in his own field that his services as an adviser are much in demand. Indeed the university lecturer may well emulate the Greek Thales who, chided for his failure to be rich when he showed himself so wise, promptly secured a monopoly of olive presses and made himself a fortune. Experience in industry is regarded as a major prerequisite, and Professor Baker considers it worse than useless to continue men on to post-graduate courses immediately following their undergraduate years.

Nowadays, as in the case of nuclear engineering, the call for team work embracing several branches of knowledge is increasing, and the part to be played by the universities becomes more and more important. It is perhaps significant that Sir John Cockcroft and Sir Christopher Hinton were both trained at Cambridge. The rate of progress, too, is so great that many become involved in forms of engineering unheard of in their undergraduate days. Here too the value of a broad fundamental training is apparent. What is more, basic engineering principles find applications in many different fields often entirely unrelated. Osborne Reynolds—another Cambridge man—by his flow and similarity studies provided information of value not only to marine and aircraft engineers but also to the designers of steam and gas turbine blading. Inglis, a civil engineer, was able to point out that the locomotive which appeared to contradict his theory of the effect of hammer blow on girder bridges was in fact incorrectly designed. Sir Charles Parsons not only invented the reaction steam turbine but also made contributions to electrical engineering and the design of astronomical telescopes. He also sponsored experiments in the manufacture of synthetic diamonds.

ARTS-SCIENCE COURSE

For the future, two rival trends may be discerned: one towards increasing specialisation; and the other towards a more liberal form of engineering education. Many places have experimented with courses of arts lectures designed to help the technologist towards a fuller and richer preparation for life. In Cambridge, a residential university, this "top dressing" is not considered necessary, but for many years courses on management and industrial psychology have been included in the curriculum. Growth in management studies are anticipated and also in the treatment and application of the physical sciences.

Within the University the importance of science and technology is clearly securing wider and wider recognition, and an honours course has been proposed combining two years' work for a part of an existing arts Tripos and a new course in science extending over three terms and the preceding long vacation. The science course is intended to be narrow but deep, and an initial course with the subject "Radioactivity and the Atomic Nucleus" has been suggested.

But whatever other proposals are made, it is certain that the engineering department will

continue in its policy of breadth and fundamentals. At present there are just short of 700 undergraduates, with a staff comprising 4 professors, 6 readers and 63 other teaching and research officers. The engineering laboratories are still growing and the new building opened by the Duke of Edinburgh in 1952, then a single spline, now has the centre stroke of an E-plan; the steel frame of the bottom stroke (a fluid mechanics laboratory) is already erected and plans for the final wing are in an advanced stage.

The facilities for providing a sound engineering training already largely exist; it is important that the best use be made of the products. As Sir Charles Inglis noted in his presidential address to the Institution of Civil Engineers in 1941: " . . . engineering firms are with increasing persistence asking for young men of exceptional ability, but having got them, not infrequently they have no idea how to utilise and develop this latent talent . . . razors are poor implements for cutting bricks, and a chisel, if used as a screw-driver, is apt to lose its edge."

I.E.E. AT MANCHESTER

The organisers of the summer meeting of the Institution of Electrical Engineers, which was held in the North Western Centre with headquarters at Manchester last week, adopted the wise course of providing a programme which was not wholly technical, as some hold these gatherings should be, nor mainly social, which is the opinion of another school. As a result it was possible for the members of a party of over 600 not only to add to their technical knowledge in more than one field, but to make " contacts " which may well turn out to be of future value. As an unusually large proportion of those attending were young they were given the opportunity of becoming acquainted with some of the more mature members of the profession to which they belonged.

Though there were no formal meetings the programme included visits to works where a great variety of electrical equipment could be seen in course of production; to factories in other industries where its application could be appreciated; to both conventional and unconventional power stations, where useful comparisons of practice could be made; to the University, where some idea could be gained of what was being done in the fields of instruction and research; to a demonstration of the most recent contribution of electrical equipment to progress in medical science; and to a television studio where the " back room " organisation of the programmes was demonstrated. Unfortunately no one visitor, not being endowed with the qualities of the mythical Irish bard, could inspect more than a few of these items, but it was open to everyone by judicious selection to add a little to his or her knowledge in at least one field. Business and pleasure were combined in an all-day visit to Calder Hall and the Lake District. Municipal, scholastic and private hospitality were enjoyed in full measure throughout the meeting.

" JUNIORS " IN SWITZERLAND

It has always been the aim of the Junior Institution of Engineers to cater for a wide range of engineering interests. This year's summer meeting, held in Switzerland from June 29 to July 8, was no exception to the rule. The meeting was informal, with no papers and no speeches, but it would have been difficult, if not impossible, to have covered a greater variety of subjects in the time available. All three basic branches of engineering—civil, mechanical and electrical—were represented in the places visited.

In such a country as Switzerland, where Nature's lavish hand with scenic attractions has at the same time created so many problems in transport and communications, it is inevitable that civil engineering should come first to mind. Roads, railways (adhesion, rack and funicular), electric power transmission lines and dams provided ample scope for study, especially during the first part of the tour. Not the least interesting of the railways were some of the construction and maintenance lines, not used for passenger transport, which ascend the mountain sides and on which cars are hauled by cable up inclines which at times approach the vertical.

HYDRO-ELECTRIC POWER

To an engineer, Switzerland also suggests water power, and it was appropriate that the first official visit of the meeting should be to a hydro-electric power undertaking. Three power stations, Innertkirchen, Handeck I and Handeck II, all belonging to the Kraftwerke Oberhasli A.G., were seen by the party. All three are equipped with water turbines of the Pelton-wheel type, the most powerful being those at Innertkirchen, where each of the five machines installed develops 65,000 h.p. Handeck I, which is the oldest of the three stations, is the only one housed in an orthodox building; the other two are underground. Handeck II is still under construction, only two of the four turbines for which it is designed having yet been installed.

Developments at Handeck II focussed attention on the question of Swiss water power generally, and it is worth mentioning that exploitation of the water power resources in that country has proceeded, and is proceeding, at such a rate that in about 10 years the limit will have been reached. Swiss water power, like British coal, is not, as was once thought, " inexhaustible." There is therefore a marked interest in Switzerland in the only obvious alternative, atomic power.

Nevertheless, water power will continue to be of great importance, both in Switzerland and elsewhere, for a long time to come, and from seeing the installation and use of hydro-electric equipment, a natural move by the party was to see its manufacture. After a journey across some of the most celebrated scenic parts of the country, passing, incidentally, the Grimsel Dam, which impounds some of the water for the Oberhasli undertaking, the party arrived at Zürich, which became the headquarters for visits to works in the northern part of the country.

MECHANICAL ENGINEERING

Three representative engineering concerns were visited on successive days, the companies being Escher Wyss Maschinenfabrik, A.G., Zürich; Gebrüder Sulzer, A.G., Winterthur and Oberwinterthur, and Georg Fischer, A.G., Schaffhausen. From the factories of these three firms comes a range of products covering practically the whole of the Swiss manufacturing industry, with the exception of the highly specialised branches such as watchmaking, and between them the concerns in question can supply anything from domestic hardware to machine tools, from textile machinery to air-conditioning plant, and from steam and gas turbines to the largest Diesel engines made. Many different types of component are also made for other users; these include castings of all sizes from repetition work to single items weighing 40 or 50 tons. The visits could be said to cover a true cross-section of Swiss engineering.

Certain common features were apparent. Swiss engineering is based on imported raw materials, and a very large part of its output is exported. It has therefore to remain well in the forefront of technical progress if it is to retain the position it has reached, and it was obvious in all the works visited that this matter was given due consideration. The research and development facilities provided were all of a uniformly high standard, and their use was not always confined to the products of the firm concerned. At Escher Wyss, for example, where the production accent is on steam, gas, water and air turbo-machinery, there was an interesting example of production equipment which had been designed and built by the company. In these works, where the two remaining Handeck II turbines are being built, iron castings up to 40 or 50 tons in weight are produced, and the machine shop is equipped on an appropriate scale. To deal with large cast or fabricated turbine casings and similar components the company had need of a 50 ft. vertical boring mill, and finding it impossible to buy what they required, made the machine themselves. It has several unusual features, among which is the fact that the columns, that on normal machines are fixed, can be removed and re-erected in any one of three different positions, to suit the work in hand. By means of this design it has been possible to provide a machine which will handle the very large work passing through the shops from time to time, and will also deal with smaller components; it is thus continuously in use.

Similarly, at the Sulzer works, there is a large, well equipped three-storey building, with a basement housing heavier plant, which provides for material, chemical, metallurgical and physical testing, both for fundamental research purposes and for checking purchased materials. Specialised sections of the laboratories deal with Diesel engines, heating and ventilating plant and other branches of the company's business. Incidentally, it is of interest to record that it was at the Sulzer works that Rudolph Diesel worked as a trainee in 1879. The same facilities for research and development exist at the Fischer works, and here again the party saw some machinery developed and built by the company to meet their own requirements.

But what might be called the " non-manufacturing " expenditure is not confined to the provision of laboratories. Welfare and training facilities and canteens are of a high standard in all the works visited, and the party was shown an undertaking, run by one of the companies, which is probably unique. This is the Iron Library, operated by a trust foundation established by Georg Fischer in 1948. (See " The Georg Fischer ' Iron Library ' at Schaffhausen," ENGINEERING, vol. 173, page 592, 1952). Under the terms of its deed of establishment the Iron Library collects and preserves historical and contemporary literature on the production, working and uses of iron, and provides facilities in the Library for research, free of charge. In the short time since its foundation the Library has amassed a collection of over 10,000 books in many languages, dealing with various aspects of iron mining, production and working in all parts of the world.

A visit to a brewery, where one of Switzerland's few remaining steam railway locomotives, a Kraus Maffei engine of about 1907, was seen at work, and, on the return journey, a glimpse of Rotterdam railway station, rebuilt in modern style after being destroyed during the war, kept the variety theme operating to the end of the meeting.

PASSING ON IDEAS

Meetings of this kind are becoming increasingly popular; it might be worth asking if they do any good, besides being a pleasant way of passing the time. Modern engineering has become so complex that specialisation is unavoidable, and therein lies one of the dangers of modern industry. It is very easy to specialise to such an extent as to lose contact with other branches of engineering, and so to miss much that is of value. For broadening one's outlook there is nothing better than making personal contact and seeing the other man at work, whether he be engaged in one's own special sphere of activity, or in some other quite different. Many a good idea has been passed on by such contacts; it is a two-way traffic, which can benefit both parties. The opportunity to see what is going on else-

where is one which ought not to be missed. Meetings like the Juniors' provide such opportunities, and in that fact lies ample justification for them.

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WHITWORTH SOCIETY'S TYNE VISIT

This year's summer meeting of the Whitworth Society took place at Newcastle-upon-Tyne on June 13 and 14, and was opened with an informal dinner held at the County Hotel.

The principal feature of the summer meeting was the visit paid to the shipbuilding organisation of Swan, Hunter, and Wigham Richardson, Limited, at Walker and Wallsend-on-Tyne, at the invitation of the Society's outgoing President, Mr. P. L. Jones, M.C., M.I.C.E., M.I.Mech.E. The visit enabled members of the Society to view many of the latest developments at the company's establishments at these two centres.

It may be recalled that the originally separate companies, C. S. Swan and Hunter Limited, and Wigham Richardson and Company, were amalgamated in 1903, and that, as now constituted, the parent organisation controls three shipbuilding yards—the Wallsend and Neptune shipyards on the Tyne, and the Clydeholm Shipyard of the firm's subsidiary company, Barclay, Curle and Company, Limited, at Glasgow. There are also three engineering works in the organisation, namely, the Neptune Works, and those of another subsidiary, the Wallsend Slipway and Engineering Company, Limited, on the Tyne; and the North British Engine Works of Barclay Curle, at Glasgow. In addition, there are three ship-repairing establishments: two on Tyneside and one on the Clyde. All of these have dry-docking facilities.

Some members of the Society visited Newcastle on June 12, prior to the commencement of the summer meeting, to witness the launching of the Llanishen, an oil tanker of 31,000 tons deadweight, at the Wallsend Shipyard. The Swan Hunter organisation constructs vessels of several types and a wide range of marine machinery, but only a portion of these activities could be inspected during the tours. Extensive reconstruction of the yards is taking place at the present time, to enable greater use to be made of construction by welded fabrication, instead of by riveting. In this connection, much evidence was encountered showing how quickly the highly-skilled trade of riveting is being replaced in every direction by welding. The work of building ships has to proceed at the same time as the reconstruction of the shipyards, so that partly-riveted ships, fabricated ships, and the development of large new bays for fabrication work, were all available for examination. Fabrication entails the lifting of larger and heavier parts and an interesting feature of the visit was to see how the existing cranes are being replaced by new ones capable of handling loads of up to 40 tons.

A new dry dock, suitable for ships of up to 45,000 tons, was inspected. An interesting feature of this structure is that the gate hinges outwards and downwards, and that all oil, water, steam and electric services are arranged in underground ducts around the dock. These devices enable the very quick servicing of ships to be achieved. At the time of the visit, the 28,000 ton Capsa was in the new dock being repaired and repainted, the painting being performed with the aid of large rollers.

At the luncheon provided by the Swan Hunter company, Mr. Jones retired from the presidential chair and inducted his successor, Mr. Ernest Markham, M.I.Mech.E., into office.

AUSTRALIAN AND U.S. MARKETS

The great improvement in the Australian balance of payments for the financial year ending June 30, 1957, augurs well for the future of British exports to Australia. The Australian export total at £A994·9 million was the highest ever recorded. Coupled with import restrictions this resulted in a favourable balance of trade of £A276 million compared with deficits of £A39·2 million and £A46·8 million in the two preceding years, and the record surplus of £A335 million in 1952-53. Now that the drought, which has threatened to reduce the output of primary products, has broken it is hoped that the level of exports will be maintained in 1957-58.

In past years there has been a tendency for the Australian Government to relax import restrictions too rapidly following an improvement in the balance of payments. The result has been a rapid worsening of the position followed by the need to re-impose controls. No sweeping changes are therefore to be expected in the immediate future, but the relaxations already announced should be sufficient to reverse the downward trend of British exports to Australia which has persisted since 1955.

The fall in exports to Australia in 1956 was more than counterbalanced by increased exports to the United States, which in that year became the largest individual market for British exports, taking goods to the value of £244 million compared with £240 million in the case of Australia. In the early months of 1957 there has been a further rise of about 25 per cent. in the value of exports to the United States. While a decline in expenditure on armaments following a disarmament agreement might cause a temporary recession, and a further decline in commodity prices might lead to some difficulties, the general expectation is of a further expansion of American industrial activity in the autumn. The rising trend of British exports to the United States is therefore likely to continue. If this is accompanied by an improvement in demand from Australia, the prospects for British exports as a whole may well be set fair for the next twelve months at least.

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THE PACE SLACKENS

Nearly all economic surveys are a reflection on things past, and few throw a very clear perspective of things to come. Yet they offer a good opportunity to scan a long period and to produce conclusions free from the stresses and distortions of the present day. The United Nations' *World Economic Survey*, 1956, reviews the development of the world economy in 1956, but places it in the full context of post-war industrial development.

The report's principal conclusion is that, while the new climb in world production which began at the end of the Korean war has continued, almost everywhere the pace had slackened in 1956. The loss of economic momentum originated as much in the realm of Government policy as in the area of private enterprise. On the prospects for the current year, the authors are cautious: "Though on balance the outlook appears to be for some continued rise in the coming months, the margin of uncertainty is greater than a year ago." The main reasons put forward for this uncertainty are the rise in costs and the fact that in most countries "the growth in productivity failed to match the increase in wages." Another is the unsatisfactory state of international trade, with many countries unable to check growing deficits in their balance of payments position. In the case of Germany, the problem was the reverse one of a growing surplus.

Balance in international trade on a multilateral basis is being sought through the gradual abolition of restrictive measures. It remains one of the major problems of to-morrow.

Letters to the Editor

MACHINE FOUNDATIONS

SIR, We have read with great interest Dr. A. J. King's article "Vibration and Noise of Mechanisms and Machines" in your issue of June 7, and need hardly say that we believe the importance of resilient mountings in this connection cannot be too widely disseminated.

We would, however, like to point out that with the use of a properly designed mounting, as a result of the reduction of the disturbing forces, in many cases the machine need no longer be bolted to the floor, so that particularly in the case of machine tools an entirely new conception of machine shop layout on a "mobility" basis is immediately opened up.

We have evidence of many machine shop installations in the United States, where machine tools mounted in this way are re-arranged whenever a different layout can achieve worthwhile savings in costs for any particular production run, and in one case at least a reserve of machines of different types and sizes is permanently held, from which particular machines are drawn as and when they are required. This installation was described at some length in the September 20, 1956, issue of the *Iron Age*.

Yours faithfully,
for Cementation (Muffelite) Limited,
A. S. BYTHWAY,
Managing Director.

Cementation (Muffelite) Limited,
20 Albert-embankment,
London, S.E.11.
July 13, 1957.

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BOMB DISPOSAL

SIR, There are many people who remember the work of the bomb-disposal squads during the last war. Their work continues. Each week some 20 reports are received of actual or suspected unexploded missiles of 1939 to 1945 vintage. The work of the squads was, and still is, indispensable. In the event of war, it would be beyond the capacity of the Regular Army bomb-disposal unit to deal with the situation. There are therefore bomb-disposal units of the Army Emergency Reserve which would rapidly be mobilised to deal with unexploded bombs and missiles; these may well be as menacing to this country as they were in 1939 to 1945. Volunteers are needed to increase the efficiency of these vital reserve units. Officers with knowledge of mechanical, electrical, civil engineering and kindred professions are needed.

Subject to their attendance for 15 days' annual training, volunteer officers of the A.E.R. are paid at the same rate as Regular officers, with allowances, plus an annual bounty of £5 for the first three years and £10 thereafter. Officers and all ranks do one training period of 15 days each year, when they learn bomb-disposal techniques and how to handle the specialised equipment. They may also do a few days' additional training, if they wish. Volunteers are welcomed from anywhere in the United Kingdom. Training is usually done at Horsham in Sussex and, of course, free rail travel is given to and from this training.

I feel sure that there are many to whom the bomb-disposal Army Emergency Reserve Units must appeal. Those who are willing and ready to serve the country in an interesting and vital role, should the necessity arise, are invited to apply to me for further details.

Yours faithfully,
P. J. HANDS,
Lieutenant-Colonel,
Commanding,
137 Bomb Disposal Regt. R.E. (A.E.R.).

Broadbridge Heath Camp,
Horsham,
Sussex.
July 9, 1957.

Weekly Survey

Cover Picture: *Karapiro hydro-electric station on the Waikato River, North Island, New Zealand, came into operation in* 1947–48, *with three units each of* 30,000 *kW. It is one of ten hydro-stations either built or being built on the Waikato River, with a total projected capacity of over one million horse-power. Behind the dam is an artificial lake* 14 *miles long, on which took place the rowing events of the British Empire Games held in New Zealand in* 1950. *To form the lake, an existing power station was completely submerged.*

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Investment and Inflation

It is apparent that the renewed vigour of inflation is occupying the Government's attention. The Chancellor of the Exchequer's warning in his speech last week that the danger of accelerated inflation has grown, and the series of meetings since then among Ministers, has led to the rumour that active measures are under consideration. Gossip about an autumn budget has been quickly scotched but the impression, and hints were given in this direction in the Chancellor's speech, is growing that the Government will not hesitate to cut back investment in the basic industries if they consider that inflation is getting out of hand.

This is the easy solution but it is not the right one. The country is faced with the long-term need to build up an export surplus and this can only be done by making a draught on current goods and services. Inevitably there follows a strain in the home market once full employment has been achieved. Under such conditions it is politically difficult but economically right to find ways of cutting down consumer expenditure rather than capital investment. Consumer expenditure can only be reduced by holding down wages below the rate of increase of productivity or stimulating a large increase in saving. It is much easier for a government, however, to cut back the investment programmes of those industries which it has under immediate control.

It is an unfortunate time to restrain the basic industries. Coal mining is beginning to show significant benefits from long-term investment. The iron and steel industry is shortly to divulge the next stage of its development programme. Electric power, which has been something of a spoilt child in the eyes of all governments since the war, can always claim that rising industrial output cannot be sustained without rising electricity generating capacity. Atomic energy is critical now both for long-term energy supplies for home industry and as an export industry. Transport, especially the railways, is beginning to respond to larger capital investment. The candidates for delay in this list are probably steel and transport but it will be unfortunate if their programmes are axed. It is possible that the brave resolutions to cut back capital expenditure may well take the form which these exercises have often done since the war, namely, to reduce marginal government expenditure and certain investment programmes on paper below figures which have never been published. This is a kind of economic homeopathy which has produced few results in the last decade, to judge by the purchasing power of the pound.

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France Ratifies the Common Market

Up to the last moment, it seemed possible that political marriages of convenience in the French Chamber of Deputies might stop France's ratification of the Treaty of Rome which establishes the European Common Market. In the event, however, ratification went through with a reasonable majority. This has given a good send-off to the series of parliamentary debates in each of the six countries comprising the common market. The French have for long been considered the most sensitive to the problems of economic union and the recent change of government has not brought much greater prospects as yet for a more stable franc. Ratification of the Treaty of Rome by all six is now as sure as such things ever can be and Germany has already followed France's example.

It is significant that the Prime Minister chose in the middle of last week to reaffirm his faith in the Free Trade Area. This was done in a speech made at a time when the Prime Minister's Conference was still in session. The Free Trade Area was one of the subjects on the agenda and the Commonwealth representatives had the opportunity to express any distastes they might feel for the idea of closer European unity. The Prime Minister emphasised the need to set negotiations afoot once more and to take the basic decisions in the near future. Risks will have to be taken. It seems likely that there will be intensive diplomatic activity on the Free Trade Area this autumn. There can be little doubt that those in favour of the whole idea will wish to establish the broad principles of the Area and fit in the details later. The critical question which neither the Government, organised industry nor the trade unions have answered formally yet is how far the Government is going to be able to go in principle without detailed horse trading in this country on tariff reductions and the "harmonisation" of wages. The voice of the weak will be heard soon enough if the Free Trade Area means specialisation and the prospective destruction of marginal industries and companies. The trade unions will have much to say about being committed to "harmonisation" of wages without detailed discussions at industry level. These two vested interests alone could raise powerful opposition if they were not handled with care. The diplomatic talks this autumn, though complicated enough, may be a smaller undertaking than the persuasion of powerful interests in this country that they should support the Free Trade Area.

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Greater Freedom for Local Authorities

In 1955 local authorities spent £528 million on building, transport, plant and machinery. This represented over 18 per cent. of the total outlay under these headings in that year. No later figures are available. Local authorities are therefore big spenders on equipment coming from the engineering industry. They spend as much in a year as all the public corporations put together and about half as much as companies. It is in consequence important to note in passing the latest White Paper on Local Government Finance (England and Wales) published by H.M. Stationery Office (Cmnd. 209). This White Paper sets out certain changes proposed in the central Government's control of local authorities' income and expenditure.

The main changes are to strengthen the rating system to a modest extent and to make a major change in the system of grants from the central Government to local authorities. A new general grant is to take the place of 12 existing specific grants for particular services, among which the most important is education. The result of this change will be to give local authorities greater flexibility in their spending policy. Medium and long-term policy will still be controlled by the Ministry of Housing and Local Government since the general grant will be reviewed every few years, but within that period local authorities will be at liberty to modify their outlay as between education, the health services, fire and town planning. The general grant is put together on a complicated formula based on population and age groups. It is apparent from this change that local authorities will be freed from interference by the central Government on a great many matters of detail and short-term policy which may in turn affect their spending on the different services they perform for ratepayers.

The main exception to the new system is highway grants. After discussion about the basis of distribution it was found impossible to devise an acceptable scheme of allocation between different local authorities. The Government has therefore decided to leave the present system as it is for the time being and to re-open the question once the new general grant scheme has had a chance to run itself in. There is thus no change under the finance arrangements likely to affect road expenditure policy for sometime to come. As for the rest, engineering concerns have been warned that local idiosyncrasies may have somewhat more play in allocating capital expenditure in future than has been the case in the past.

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Contractors' Future

Uncertainty concerning their companies' prospects is the keynote of the recent annual statements by chairmen of civil engineering and contracting organisations. Sir Richard Costain, chairman and joint managing director of Richard Costain, Limited, reported better results in 1956 than the previous year and forecast that the improvement would be maintained in 1957, but said that looking further ahead was "much more difficult." He summed up the situation as follows: "we are facing increased foreign competition abroad and the prospect of a falling-off in capital expenditure at home unless the Government take action in time. I would like, too, to feel more confident than I do that the private building of property for sale and rent was finally out of danger of unwise political action."

Considerable emphasis was placed on rising costs by Mr. W. K. Laing, chairman of John Laing and Son (Holdings), Limited, and on the difficulties of ensuring a smooth flow of the necessary raw materials. Mr. Laing, whose company have considerable experience of Canadian conditions, said that although much has already been done to streamline planning and progressing, "Britain has not yet seen all that an up-to-date and fully mechanised building and civil engineering industry can contribute to the economic progress of our country." Like Sir Richard Costain, Mr. Laing considers the challenge of competition is becoming more keen, and warns his company to be "continually alert and ready to surmount fresh difficulties which will doubtless face us in the future."

Another large company, the Limmer and Trinidad Lake Asphalt Company, Limited, share the cautious outlook of Costain's and Laing's. Their chairman, Sir John Hathorn Hall, considers that after weighing up the factors likely to affect the coming year's results, "with all the difficulties and dangers that lie so ominously ahead, it would be unduly sanguine to expect that the existing rate of progress and expansion should continue unchecked through yet another year." Thus the large contracting firms expect a fall in activity, due to competition, credit restrictions and to cuts in public expenditure. At the present time, their expectations would appear to be very much on target.

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The International Monetary Fund

Countries which suffer from dollar shortages are likely to experience increasing difficulty in securing loans from the International Monetary Fund. The Fund has just completed the most active year in its history during which, among other loans, it provided a credit of 1,300 million dollars to this country to help in restoring confidence in sterling following the Suez crisis. It is, however, expected that there will be a reduction in the number and in the average size of

loans in the immediate future, partly because it is considered that the most urgent cases have already been dealt with and partly because of a decline in the available resources of the Fund.

Loans made by the Fund are on a relatively short-term basis and, provided repayments are made according to schedule, it will not be long before additional resources become available. In practice, however, it is not always possible to ensure that loans are restricted to cases where short-term repayment is possible. The criteria applied by the Fund are that drawings should in the first place be restricted to 50 per cent. of the quota allotted to each country. If additional assistance is required this should, according to the managing director of the Fund, be in support of a well balanced policy of such a character that it is possible to entertain confidence in the enduring stability of the currency concerned and at a realistic rate of exchange.

Examples of recent loans include one of 125 million dollars to Japan and another of 200 million dollars to India to assist in overcoming capital shortages due to the world wide investment boom. In addition, a number of agricultural countries have been assisted to meet seasonal balance of payment crises. Perhaps the most important problem to be faced in the immediate future is that of France, whose trade deficit in 1956 reached record proportions. A loan of 262·5 million dollars, representing 50 per cent. of the French quota in the I.M.F. was made, in September, 1956. If, as seems probable, further assistance is required it is doubtful whether France can be held to satisfy the condition relating to a realistic rate of exchange. Apart from the need to ensure replenishment of its own resources through repayment of loans, the Fund must also in shaping its future policy have regard to the desirability of avoiding further stimulation of the present world wide inflation.

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Slowing Down in Germany

Expansion in the German engineering industries is at a greatly reduced rate and there are signs that further slackening will take place. This is the general conclusion reached by Germany's leading economic research institutes. In the engineering industries output is currently down about 1 per cent. below last year's level and delivery dates for most products have fallen from one year to six months. The rate of building is running 15 per cent. below that of last summer and home market orders for machine tools in April and May were from 18 to 48 per cent. less than in the corresponding period in 1956. Total industrial output is about 4½ per cent. above last year's level, but this compares with an 8 per cent. rise in 1956. In the engineering industries weak spots have developed, particularly in motor cycles, heavy trucks, locomotives and tractors.

This slowing down of engineering activity was confirmed by Dr.-Ing. E. H. H. Reuter, chairman of Demag A.G. "Although the German engineering industry can point to encouraging progress in its efforts to secure additional employment by means of investment and measures of rationalisation," he said, "it should be noted that the upward trend noticeable in 1955-56 shows signs of slowing down." Dr. Reuter pointed out that the average number of hours worked a week in the German engineering industry dropped from 50·6 hours in November, 1955, to 47·1 hours in the same month last year, i.e., by 7 per cent. within 12 months. Advances in productivity offset some of these reductions in working hours, but the turnover per head, nonetheless, dropped by 2 per cent., the first drop to be recorded since the war (with due allowance being made for price changes).

Dr. Reuter's review of the factors influencing engineering development in Germany is one of the most instructive of those published so far. His criticism of the hampering of exports by official measures, because Germany's export surpluses are getting out of hand, is based on the fact that "export business cannot be turned off and on like a water tap." It would be instructive to know why German industry is finding it so hard to restrain what British industry finds equally difficult to achieve.

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Car Components

The revival of output in the motor vehicle industry has led to a considerable improvement in the fortunes of their component suppliers, but the reports on the trading in 1956 do not make very cheerful reading. Mr. W. B. D. Brown, chairman of the Glacier Metal Company, Limited, spoke for many of his colleagues when he said "we are now reporting much reduced profits and we are very concerned about this because such a position contains a threat for the future." Simms Motor Units, whose own activities are affected more by the demand for commercial vehicles than for cars, reported a fall of only £157,000 in trading profits to £1·04 million. The threat exists, however, and Simms are meeting it by adding new products to their range—a turbocharger for internal combustion engines and a hand starter for Diesel engines—to keep to the forefront of technical progress. They are also diversifying in order to reduce their dependence on the motor industry. Their entry into fuel-oil burners, heating and ventilating systems and domestic electrical appliances (through the purchase of established companies) is evidence of what Mr. G. E. Liardet, their chairman, calls "a policy of spreading the range of our products over a much wider field."

Two other companies whose annual reports were published last week, the Pressed Steel Company and Ambrose Shardlow and Company, both mention the reduction of business which followed the fall in car demand last year. Ambrose Shardlow's chairman, Mr. T. P. N. Burness, mentioned that various expansion schemes had come to fruition and that his company were now in a much better position to deal with "the rising demand for larger types of crankshafts." But, basically, the company are dependent on motor vehicle production for the bulk of their activities. Mr. Alex Abel Smith, chairman of Pressed Steel, had the recession in refrigerator sales to add to that in private cars. On this subject he said that car-body business was picking up, but that "it would be a bold man who ventures to forecast what the rest of the year holds in store." Pressed Steel have a valuable railway wagon business but they, and most of the other large makers of car components, are still mainly dependent on the prosperity of the motor industry which, in turn, is vitally affected by Government credit policy.

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A.B.C. of Exhibiting

The considerable success of the International Machine Tool Exhibition held at Olympia, London, last year was due largely to careful planning and efficient organisation. The methods by which this was achieved are described in a booklet *Report of the Exhibition Committee on the International Machine Tool Exhibition, London*, 1956, published by the Machine Tool Trades Association. The description of what was done in the two years which followed the appointment of the Exhibition committee is an object lesson in the holding of trade shows. Something was doubtless borrowed from the experience of others, much arose from the Association's previous post-war exhibitions, held in 1952 and 1948, but great deal was learned the hard way at the exhibition itself.

A number of recommendations concerning the industry's future exhibitions are made by the committee, relating both to organisation and to publicity. One of the most basic is that the drawing up of stand plans should be delayed until applications for space have been received. Another is that the amount of space applied for by a member should not, in any circumstances, be regarded as the basis on which to allocate. One of the most difficult of the tasks facing the committee is the decision concerning the amount of space to allocate to each member to allow "a representative though not necessarily a complete display." The experience of 1956 suggests that it is better to select items, e.g., a special machine which can be well displayed and demonstrated, rather than cram the stand with everything the firm makes. In order to determine "the reasonable overall area of the stand" a factor of 2·5 times the square footage of the exhibits was applied universally.

Experience in installation and dismantling of the exhibition—it proved most satisfactory to appoint a sole contractor to the exhibition—in layout and stand fitting, in exhibition service and in staff organisation, is briefly described. The information on public relations and publicity, including catering and social arrangements, is well thought out, practical and should prove most useful to anyone facing similar problems.

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Railway Modernisation

Further reference was made last week to the progress of the modernisation programme for the railways, in the debate on the ninth Annual Report of the British Transport Commission. The Minister of Transport and Civil Aviation said that 400 new Diesel railcars had been delivered by the end of 1956 and that remarkable increases in receipts had followed the introduction of this type of train. The Diesel locomotive programme is inevitably less far advanced, but deliveries are already being made against the original orders for 230 locomotives and the Minister said that further orders were about to be placed. Here there is some degree of conflict between the desirability of extensive testing in service of the various types of locomotive on order and the need to proceed with modernisation as rapidly as possible. As the Minister said, the worry is not that the railways will achieve too little but that they will achieve it too late to regain the traffic they have lost to the roads. However, apart from the work in hand in the railway workshops, orders placed with the independent locomotive builders in the last two months have covered 67 Diesel shunting locomotives and a repeat order to the North British Locomotive Company for 28 main line Diesel-electric locomotives.

The main-line Diesel-electric locomotives are, of course, intended for use only in an interim period pending main-line electrification. The first main-line electric locomotives, ordered in March of this year, are expected to be in operation on the Manchester-Crewe section by October, 1958.

While public interest tends to concentrate on developments in the locomotive field, the modernisation of rolling stock for goods traffic is probably more important for future profitable operation of the railways. Last year passenger-miles were higher than in any year since nationalisation but the downward trend in freight continued. It is therefore encouraging that the Minister was able to report that the fitting of continuous brakes is ahead of schedule, and that attention is being paid to the introduction of new designs of wagon including 400 wagons for the transport of cement in bulk with provision for discharge under pressure; special trucks for the transport of bricks, tiles and slates; and large fork lift trucks and new types of cranes which will be capable of lifting whole lorry loads from lorries on to trucks. It is to be hoped that the programme, which is now beginning to show some results, will not have to be curtailed as a result of continuing inflation. Any reduction in the programme at this stage might well jeopardise the results of the whole modernisation scheme.

WELDING IN ENGINEERING PRODUCTION

Concluding our report of the British Commonwealth Welding Conference, held in London and Saltburn-by-the-Sea from June 17 to 29, we now deal with papers describing methods for controlling the quality of welds and for the education and training of welders.

CONTROL OF QUALITY

The function of testing procedure was discussed by Mr. A. H. Goodger, head of the metallurgical department of the National Boiler and General Insurance Company, Limited, in a paper entitled: "Present Position of Testing Methods for Welding Control." He stated that probably the most generally accepted non-destructive test for weld quality was radiography. The interpretation of radiographs was reasonably easy if the person viewing them had had sufficient experience in the cutting up of joints and the correlation of the findings with radiographic images. The easiest joints to interpret were the butt welds ground on both surfaces and radiographed through one thickness; the most difficult were pipe welds.

Ultrasonic testing, introduced in about 1947, had developed more slowly than many people had hoped. This was only to be expected considering that shear waves and echo methods, although very sensitive and capable of detecting the most minute defects, gave no indication of their shape or nature unless mapped by scanning. A single echo gave an indication that was as difficult to interpret as if the signal were a bell, voltage or number.

"Control of Weld Quality in Steel by Training and Inspection," was the title of a paper by Dr. A. J. P. Tucker, of African Explosives and Chemical Industries, Limited. He stated that destructive and non-destructive methods of testing welds detected faults only after the welds had been made. Hence only indirectly did they prevent the formation of defects. The production of consistently sound welds by manual welding could be achieved only by the sound training of designers, supervisors and welders and by the proper application of visual inspection during welding. Apart from sound training and the provision of material incentives such as bonus payments, the welder should be encouraged to understand and be proud of his work.

Moreover, the welding equipment should be in good order and the root gap, root face, bevel and alignment of the work, to the design requirements. Jigs, where used, should be sufficiently robust to maintain alignment and root gap during tacking and the deposition of initial runs. The welding edges and the material, for a short distance back from the weld, should be clean. Attention must be paid to the type of coating, size of core wire, and condition of coating of electrodes, and the surest way of preventing electrodes from becoming damp was for the welder to carry them in a quiver hung at his side. Certain alloys should not be welded without preheating and the required preheat temperature should be specified on the working instructions and checked by suitable means before welding was started. Attention should also be paid to such matters as the correct arc length, welding speed, slag removal between successive welding runs, and penetration. If the procedure outlined above were carefully followed, the need for destructive or non-destructive tests would be greatly reduced.

A review of information on the "Effects of Gases on the Constitution and Properties of Ferritic Weld Metals," was submitted by Dr. W. D. Biggs, of Murex Welding Processes, Limited, Waltham Cross, Hertfordshire. He stated that oxygen, nitrogen, and hydrogen could exist in metals in solid solution, as entrapped gas, or as discrete microstructural phases. Oxygen might be present in the form of inclusions or grain-boundary segregates. The effects of nitrogen in promoting strain-ageing characteristics were well known, and weld metal had been exhaustively studied in this respect. There was rather more uncertainty over the cause of quench ageing, the cooling rate after welding providing an adequate quench. A reduction in the nitrogen content did not eliminate quench-ageing tendencies, although the results from weld metal tended to be erratic and non-reproducible in nature. Apart from ageing phenomena, those factors which lowered the ductility of mild-steel weld metal were generally associated with the hydrogen content, which was significantly higher than was the case in furnace steel.

In a paper on "The Bend Test as a Criterion of Weld-Metal Quality," Mr. J. W. Shedden described an investigation carried out in the research department of Murex (Australasia) Pty. Limited, Hobart, Tasmania. He stated that hot-crack formation in weld metal had been examined by a bend-test method, beads being deposited on test specimens subjected to bending during the welding process. A relationship had been found between the length of the cracks produced and the manganese-sulphur ratio in the weld deposits. The angle of bending had been varied to suit the carbon content of the test plates. Transverse bend tests had been made at room temperature on specimens containing a single-layer butt welded joint. The effect of varying the manganese-sulphur ratio in the weld metal had been studied by the measurement of the angle of bend for the maximum load.

"The Boundary-Zone Factor in Arc Welding," was the title of a paper by Mr. H. Thomasson, of the Canadian Westinghouse Company, Limited, Hamilton, Ontario, Canada. He stated that a study had been made, by micro-hardness testing techniques, of the weld metal and boundary-zone hardness adjacent to single-bead metal-arc welds in $\frac{1}{2}$ in. thick, 0·23 per cent. carbon steel plate. The work had indicated that beads deposited from small electrodes could produce regions of objectionably-high hardness, particularly at the first and last inch of deposit, and with peaks at the extreme ends of the welds. The width of the heat-affected zone was very narrow, particularly with small electrodes, as indicated by the rapid fall in hardness between readings at 0·002 in. and 0·010 in. from the junction. There was a marked increase in both boundary-zone and weld-metal hardness as the welding speed was increased, especially with the smaller electrodes.

Tests were also made on single-bead welds on Mn-Mo plate, containing 0·25 per cent. carbon, 1·31 per cent. manganese and 0·50 per cent. molybdenum. These tests showed similar trends except that the width of the heat-affected zone was noticeably greater. The hardness in the boundary zone was influenced mainly by the thickness of the parent plate; it increased to a notable extent as the thickness increased.

In a paper entitled "Testing of Light-Alloy Welds and Welders," Mr. N. T. Burgess, of the Aluminium Development Association, stated that possible defects in aluminium welds included tungsten or oxide inclusions, cracks, crater cracks, lack of root fusion in fillet welds, porosity, centre-line oxide-film inclusions, underbead defect in butt welds and oxide enfoldment. Methods of detection for these defects included visual or macro-examination and radiography, or the destructive nicked break test.

Periodic checks on the welder should be made. Many authorities considered that a welder's value could be assessed only after his work had been examined continuously, and the logging of all work was recommended.

EDUCATION AND TRAINING OF WELDERS

Several papers related to the education and training of welders. Mr. F. Clark, of British Oxygen Gases, Limited, in his contribution "Some Thoughts on the Training of Welders," reviewed the subject with particular reference to trade-school training for gas welding. He emphasised the care needed in the selection of suitable trainees and the essential qualifications of good instructors, and pointed out that attention must be given also to the formulation of syllabuses and to the equipment required for instructional purposes.

The development, over a 12-year period, of a successful course attended by welders, foremen, inspectors, supervisors, designers and management executives, was dealt with in a paper, "Education and Training for Welding," by Mr. H. McClymont and Mr. H. Hinxman, who are on the staff of member firms of the Aluminium Limited group. They stated that the intense interest in welding by those giving the course had been infectious and had led to increased participation and effort by candidates.

In their paper "Welding Education in Britain —The Road Ahead," Mr. G. Parsloe, secretary of the Institute of Welding, and Mr. R. E. G. Weddell, of W. G. Allen and Sons (Tipton), Limited, said that the Council of the Institute of Welding had adopted the findings of a conference, on the "Functions and Education of Welding Engineers," organised by the Institute and held in September, 1956, at Ashorne Hill. Among these findings were: that opportunities should be provided for teachers to see more of current industrial practice and that arrangements should be made for suitable men from industry to give specialist assistance to teaching institutions; that a wider range of students should be familiarised with welding practice by including, among the teaching examples for basic subjects, a greater proportion drawn from welded work; that the responsible authorities should provide for the study of welding in the later years of further basic engineering courses; and that industry should encourage the support of courses of specialist study of welding processes and practice designed for men already professionally qualified as engineers.

A paper, "Training the Welding Technician and Engineer by Correspondence," by Mr. R. M. Gooderham, director of the Canadian Welding Bureau, Toronto, Canada, described how the need for both elementary and advanced welding knowledge had been met by correspondence courses developed by the Bureau. The courses included: fundamental welding principles and practices; elements of structural steel design, and weld-quality control and inspection.

The scope of British Standard 2645, covering "Tests for Use in the Approval of Welders," was reviewed in a paper by Mr. E. Flintham, of Quasi-Arc Limited, Bilston. He concluded that approval tests for welders were a wise precaution, but they did not eliminate the need for subsequent supervision and inspection to ensure that the welding on the actual construction was of the required standard. There was, therefore, every reason why it was desirable to use the standard forms of approval tests prescribed in B.S. 2645 for the assessment of the quality of a welder's workmanship, and so avoid the chaos that could arise from the use of many varied forms of tests, which all served the same end as the standard tests but differed only in conception.

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CUTTING OILS

The range of oils made by Amber Oils, Limited, 11a Albemarle-street, London, W.1, includes a sulphloid series which contain semi-colloidal sulphur. It is claimed that the solid sulphur particles form a neutral zone between the tool edge and the swarf, and thereby prevent the swarf welding. Further additives in the oil speed the formation of a ferric sulphide film, which prevents metal to metal contact between tool and work-piece materials. As a consequence, it is reported that a very great increase in tool life before regrinding is necessary can be obtained.

PLASTIC YIELDING OF I-BEAMS

SHEAR LOADING EFFECTS ANALYSED

By A. P. Green and B. B. Hundy†*

In this article, which is concerned with the initial plastic yielding of an I-beam due to the combined effect of bending moment and shear force, various theoretical relations are reviewed which correct the simple theory of pure bending by taking into account the effect of a shear force. New experiments are described in which both the loads and plastic deformation at yielding are investigated, using model mild-steel I-beams. This work confirms and supplements experiments by other workers. It is concluded that of the existing formulae those suggested by Heyman and Dutton[5] are the most useful for design purposes.

The plastic limit analysis and design of structures falls naturally into three stages. The first necessity is to estimate the load-carrying capacity, based on the plastic yield limit, of individual beams in the structure under the given end constraints and systems of loading to which they will be subject in use. The second stage is to apply this knowledge to the structure as a whole, to discover its mode of collapse and the magnitude of the overall applied loads which could bring collapse about. The methods which have been developed for this part of the analysis are based primarily on estimates of the maximum bending moment M (called the fully-plastic moment or limit moment) which can be withstood by any individual member without serious local plastic deformation. Hence, attention is focused on the value of M when considering the effects of shear force, axial load, or constraints on the carrying capacity of individual members. Finally, a suitable load factor of safety, q, the ratio of collapse load to working load, must be chosen to allow for uncertainties in the working conditions of the structure, unavoidable variations in the strength of the structural materials, and possible errors arising from simplifications in the plastic analysis.

Deflection calculations are not a part of the limit analysis itself, though in practice they may be a ruling consideration. If so, the limit analysis must be supplemented by an estimate of critical deflections and the load factor of safety adjusted accordingly.

This article is concerned with the detailed behaviour of an individual uniform I-beam yielding at some section under the combined effect of bending moment M and shear force F, both acting in the plane of the web. The main aim is to investigate the effect of F on M in order to be able to correct, when necessary, the simple theory, in which the estimate of M is based on the assumption of pure bending with $F = 0$. Experiments on model mild-steel beams are described which provide information about both their load-carrying capacities and their modes of deformation. A survey is made of various theoretical relations between M and F which have been proposed, and they are compared with the present experimental results. Problems of buckling in the flange or web are not discussed, and the dimensions of the model beams were such that buckling did not occur. The article is, therefore, concerned mainly with the first stage of limit analysis. It is hoped, however, that the suggested modes of deformation will also help in the problem of estimating deflections.

SUMMARY OF THEORY

It is generally agreed that even if the tensile stress-strain curve of the structural material exhibits an upper yield-point, its carrying capacity is determined mainly by the lower yield stress, which is denoted here by Y. The corresponding maximum shear stress, k, depends on the yield criterion of the material, which is usually assumed to be either that of Tresca ($k = \frac{1}{2}Y$) or of von Mises $\left(k = \frac{Y}{\sqrt{3}}\right)$.

The following notation (Fig. 1*a*) is used for the dimensions of a transverse section of an I-beam: A_w is the area of the web and d its depth; b is the breadth of each flange, A_F the area including the fillets, and D the distance between the centroids of these areas.

Pure Bending.—The limit moment according to the simple theory of pure bending is

$$M_o = Y S \quad . \quad . \quad (1)$$

where S is the first moment of area, sometimes called the plastic modulus of the section (by analogy with the similar quantity in the elastic theory of beams). For an I-beam

$$S = \frac{d}{4} A_w + D A_F \quad . \quad . \quad (2)$$

Unless the bending moment is uniform over a finite length of the beam, plastic bending is localised at a so-called "plastic hinge." The regions of deformation, and the distribution of longitudinal stress σ_L across a section at such a hinge are shown in Figs. 1 (*b*) and (*c*).

The pure bending moments for the web, and for both the flanges, are respectively

$$M_{wo} = \frac{Y d A_w}{4}, \text{ and } M_{Fo} = Y D A_F \quad . \quad . \quad . \quad (3)$$

Their ratio M_{Fo}/M_{wo} will be denoted by ρ, and this, as we shall see, is an important non-dimensional parameter in relations between M and F. It is sometimes convenient to write

$$M_o = M_{wo}(1 + \rho) \quad . \quad . \quad (4)$$

Combined Bending Moment and Shear Force. The application of a shearing load F to a beam usually involves some kind of constraint at the plastic region. Since at the section where the bending moment is a maximum the shear force is zero, yielding will take place by approximately pure bending. It is only at concentrated loads or supports that the effect of shear load has to be considered. For example, yielding often occurs in a vicinity of supports or concentrated loads, since the bending moment is frequently a maximum at such sections. The more severe the constraint the greater M might be expected to be for a given F. Thus, one cannot expect a unique relation between M and F, and it is important to enquire how strongly this relationship is affected by details of loading and constraint. The following are four common types of situation (illustrated diagrammatically in Fig. 2) which arise in practice:—

(*a*) Yielding under distributed loading away from a support or concentrated load. The surface forces per unit area on the loaded flange are generally small and are not likely to exert much constraint on the plastic region.

(*b*) Yielding near a simply-applied concentrated load or at a simple support. The high compressive forces applied to one flange enable compressive stresses greater than Y to be developed in this flange and in the web nearby.

(*c*) Yielding adjacent to a support to which the beam is firmly welded so that its end section is fixed in position and direction. This is the most severe constraint likely to occur, and both the tensile and compressive longitudinal stresses may reach magnitudes greater than Y. It is assumed here that the support is strong enough not to yield in preference to the beam, though this is not necessarily true in practice.[a]

(*d*) Yielding over a short length of beam between two opposed concentrated loads each of which is either simply applied, as in (*b*), or transmitted to the beam through a strong support, as in (*c*). This may occur when the span is very short so that the regions of plastic deformation at each end join up to form one continuous region between the two loads.

There is also another kind of constraint which occurs in the flanges. In general, yielding takes place over only a short length of flange, and hence the elastically stressed material outside this region constrains the lateral deformation of the plastic material in between. This effectively increases the mean longitudinal stress in the flanges, when they are not supporting any shear load, to some value between Y and $2k$. The upper limit $2k$ corresponds to such large width-to-length ratios of the deforming region in the flange (greater than 6, say) that the lateral strain is negligible, that is, plane strain conditions prevail. If the material obeys a Tresca criterion, there is no strengthening effect since $2k = Y$, but for von Mises criterion $2k = \frac{2Y}{\sqrt{3}}$, there is an increase of 15 per cent. over Y. In many theoretical calculations this constraint is neglected, an error which tends to an under-estimate of M.

A brief account is now given of various theoretical estimates of M and its dependence on F, and of the corresponding modes of deformation (where proposed). The significance of these estimates in the light of the mathematical theory of plasticity, and the basic assumptions made, are discussed in the appendix.

When $\frac{F}{A_w} \ll k$, the shear force across the plastic section is supported entirely by the web; it is therefore convenient to consider the web and flanges separately. In certain approximate solutions this approach has been used even for values of F/A_w as high as k, though it is certain that at some value of $\frac{F}{A_w} < k$ (depending on the exact conditions of loading and constraint) part of the shear force is in fact supported by the flanges. One flange is assumed to be in pure tension Y along its length, the other in pure compression $-Y$, just as in the theory of pure bending. The two flanges, therefore, support a fixed bending moment M_{Fo}, while the moment supported

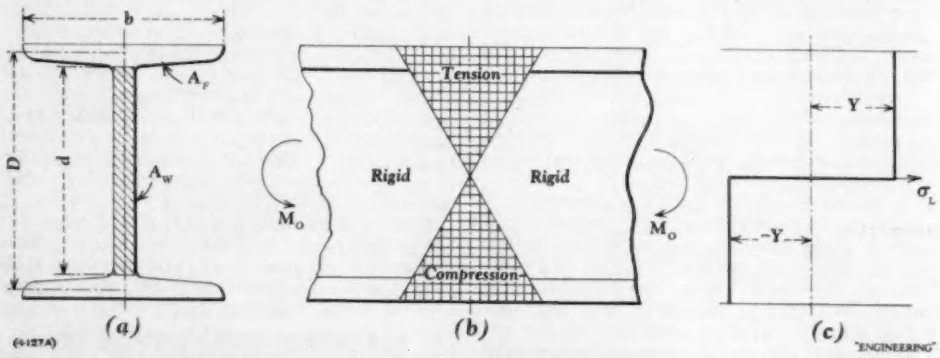

Fig. 1 The regions of deformation and the distribution of longitudinal stress at a "plastic hinge" for a rolled steel I-beam under pure bending.

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† Steel, Peech and Tozer branch of the United Steel Companies, Sheffield. Formerly with the British Iron and Steel Research Association.

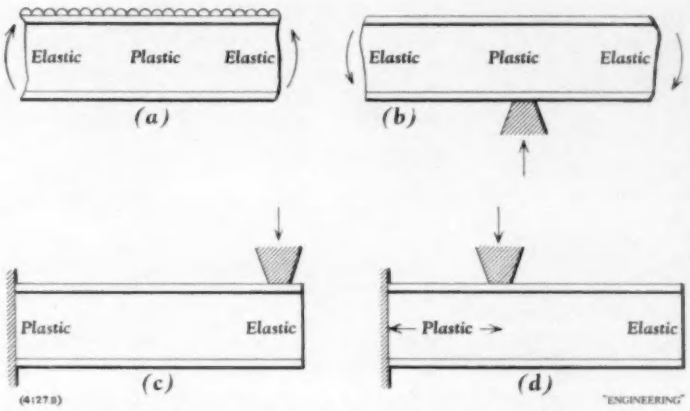

Fig. 2 Types of loading and constraint giving rise to yielding.

(*a*) Under distributed loading away from a support.
(*b*) Near a simply-applied concentrated load or at a simple support.
(*c*) Adjacent to a support to which the beam is rigidly fixed.
(*d*) Between two opposed concentrated loads, either simply applied or transmitted through a strong support.

by the web, M_w, depends on the value of F/A_w. Hence the total moment is

$$M = M_{fo} + M_w = \frac{M_o}{1+\rho}\left(\rho + \frac{M_w}{M_{wo}}\right) \quad (5)$$

and the various theories differ only in their estimates of of M_w. In all theories a state of plane stress is assumed in the web.

Horne[8] assumed the Tresca yield criterion and constructed a stress distribution over the whole of a cantilever of rectangular cross-section, strongly supported in position and direction at one end (corresponding to situation (*c*)), and carrying a shear load F at the other end (Fig. 3); he did not attempt to construct a mode of deformation. This solution, he supposed, gives the carrying capacity, M_w, of the web alone. The outer parts of the plastic region are in pure tension or compression parallel to the axis of the beam, the shear load being entirely supported over a central region. All the external stress-boundary conditions are satisfied, but the yield stress is exceeded only at the outer edges of the central plastic region, over very small areas; in addition conditions of stress equilibrium are not precisely satisfied at the boundaries between the plastic and elastic regions. From this approximate stress field Horne deduced that M_w is always reduced due to the action of shear force, according to the relation,

$$\frac{M_w}{M_{wo}} = 1 - 1{\cdot}77\left(\frac{F}{Y A_w}\right)^2 \quad . \quad . \quad (6)$$

for $\frac{F}{A_w} \leqslant 0{\cdot}396\ Y$. This upper limiting value for $\frac{F}{A_w}$ corresponds to the extension of the central shear region through the whole depth of the web.

Heyman and Dutton[6] obtained two approximate estimates of M_w. They constructed stress distributions satisfying von Mises' yield criterion across an assumed section of yielding, but did not attempt to extend them along the beam; nor did they consider deformation. The first of these stress distributions across the web is similar to that of Horne at the supported end, and the relation deduced, which is also similar to that of Horne, is

$$\frac{M_w}{M_{wo}} = 1 - 1{\cdot}62\left(\frac{F}{Y A_w}\right)^2 \quad . \quad . \quad (7)$$

the upper limit for F/A_w being 0·453 Y when the central region of shear extends over the whole depth of the web. They also constructed an alternative distribution in order to obtain estimates of M_w for higher values of F/A_w, and this consists simply of constant longitudinal stress σ_L and shear stress τ across the whole depth of the web. The relation deduced is

$$\frac{M_w}{M_{wo}} = \sqrt{1 - 3\left(\frac{F}{Y A_w}\right)^2} \quad . \quad (8)$$

for $0 \leqslant \frac{F}{A_w} \leqslant \frac{Y}{\sqrt{3}} = k$. At the upper limit, $M_w = 0$ and τ has its maximum possible value k. Equation (8) is almost identical to equation (7) for low values of $F/Y A_w$.

In contrast to the solutions described so far, Green's estimates[4] of M_w are based primarily on modes of plastic deformation, though these are constructed so that in the deforming regions there are compatible equilibrium stress distributions, obeying the yield criterion and satisfying the stress-boundary conditions. Outside the deforming regions, the motion of the assumed rigid material is compatible with the mode of deformation, but no stress distributions have been constructed. Solutions have been constructed for loading and constraint situations of the types (*b*) and (*c*) described above, and the following estimates were deduced:

With simple loading or support (*b*),

$$\frac{M_w}{M_{wo}} = 1 + 2{\cdot}51\left(\frac{F}{Y A_w}\right)\left(0{\cdot}35 - \frac{F\sqrt{3}}{Y A_w}\right) \quad . \quad . \quad . \quad (9)$$

for $\frac{F}{A_w} \leqslant 0{\cdot}191\ Y$; no solutions have been constructed for higher values of F/A_w.

With strong constraint at a strong support (*c*),

$$\frac{M_w}{M_{wo}} = 1 + 2{\cdot}13\left(\frac{F}{Y A_w}\right)\left(0{\cdot}5 - \frac{F\sqrt{3}}{Y A_w}\right) \quad . \quad . \quad . \quad (10)$$

for $0 \leqslant \frac{F}{A_w} \leqslant 0{\cdot}36\ Y$, and

$$\frac{M_w}{M_{wo}} = 1{\cdot}15\sqrt{1 - 3\left(\frac{F}{Y A_w}\right)^2} \quad . \quad (11)$$

for $0{\cdot}36\ Y \leqslant \frac{F}{A_w} \leqslant \frac{Y}{\sqrt{3}} = k$. Typical regions

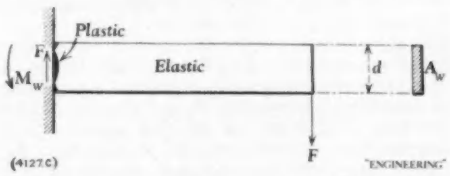

Fig. 3 Horne's solution for stress distribution in the web.

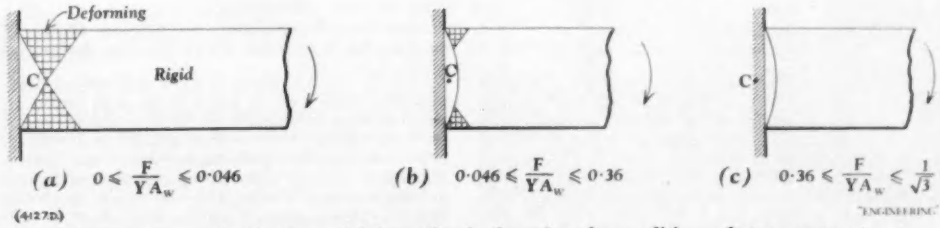

Fig. 4 Theoretical regions of deformation in the web under conditions of strong support.

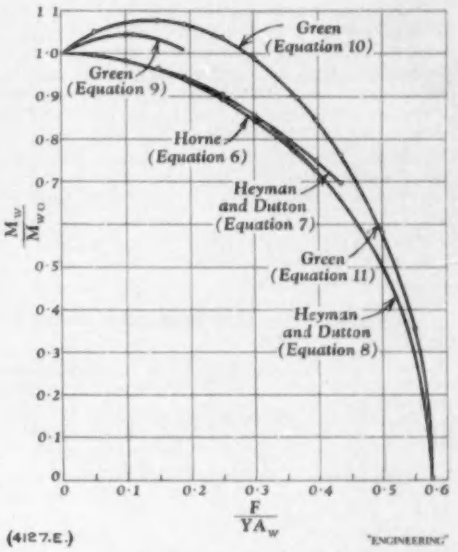

Fig. 5 Theoretical relations between $\frac{M_w}{M_{wo}}$ and $\frac{F}{Y A_w}$.

of deformation in the web, corresponding to the formulae (10) $0 \leqslant \frac{F}{Y A_w} \leqslant 0{\cdot}046$, (10) $0{\cdot}046 \leqslant \frac{F}{Y A_w} \leqslant 0{\cdot}36$, and (11), are shown in Fig. 4. The centre of relative rotation of the two parts of the beam on either side of the plastic hinge is labelled C.

The various estimates of M_w/M_{wo} are compared in Fig. 5, where they are plotted against the non-dimensional parameter F/YA_w. The differences between them are not large.

Some solutions will now be described in which the flange and web are considered together instead of separately. Leth[11] constructed a stress field over the whole of an I-section cantilever. The stress distribution across the web at the fixed end is very similar to the second type of distribution suggested by Heyman and Dutton[6] but, unlike theirs, it extends over the whole beam between the support and the end load, including the flange. The yield criterion is not violated at any point and the conditions of internal equilibrium and the stress boundary conditions are exactly satisfied except for an approximation at the junction between the flange and web. At this junction it is assumed that the shear force between the flange and the web (as far as the flange is concerned) is distributed across the whole inner width of the flange instead of being confined to the width of the web; a similar approximation has been made in elasticity theory. Unfortunately, Leth's expression for M/M_o is too cumbersome for practical use. However, for the shapes of I-beams commonly used, his estimate of M lies within about 2 per cent. of that given by the simpler result of Heyman and Dutton in equations (5) and (8). Leth's estimate is the greater for large values of F/YA_w, but is the smaller for small values; the two estimates cover practically the same range of F/YA_w.

From the approximate solutions described so far, it seems that the shear stress between the flange and web in the plastic region is negligible for F/A_w less than about $\frac{1}{2}k$, but above this value it increases appreciably as F/A_w increases, approaching k as F/A_w approaches k. This strong interaction between the web and flange makes it impracticable to consider the flanges and web separately when $\frac{F}{A_w} > k$. Leth has suggested the mode of deformation shown in Fig. 6 (*a*) for this upper range of F/A_w. The web and flanges are rigid to the left of A G H B and the whole of the rest of the web deforms by simple shear parallel to G H; the adjacent flanges are rigid and merely rotate, except for the small regions A D G and B E H which deform in simple shear parallel to A G and H B respectively. The

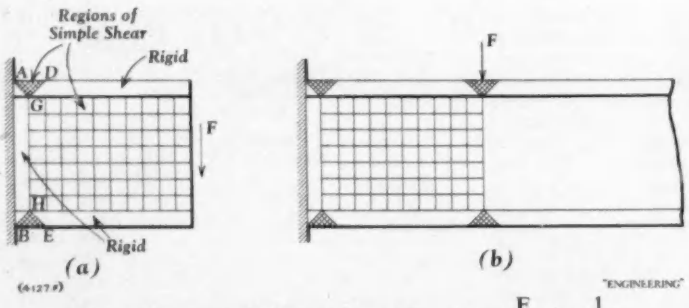

Fig. 6 Theoretical deformation modes when $\frac{F}{YA_w} > \frac{1}{\sqrt{3}}$.

(*a*) Leth's mode.
(*b*) Modification of Leth's mode.

estimate of M/M_o deduced by Leth is

$$\frac{M}{M_o} = \frac{F}{Y b D}\left(\frac{\rho}{1+\rho}\right)\left(\frac{2YA_F}{F\sqrt{3} - YA_w} + 1\right) \quad . \quad . \quad . \quad (12)$$

where $\frac{F}{YA_w} \leqslant \frac{1}{\sqrt{3}}\left(1 + \frac{2A_F}{A_w}\right)$. This upper limit for F/YA_w corresponds to the shortest beam which will contain this mode of deformation. At the other extreme, the estimate of M/M_o becomes much too large (> 1) for values of M/M_o less than about $\frac{\rho}{(1+\rho)}$, the minimum value covered by the other formulae. The main shortcoming of this mode of deformation is that in practice there is likely to be either a strong support, or a simply applied load with the beam continuing on beyond the load point, at each end of the region of shear, as envisaged in case (*d*). The flanges must then deform at both ends as shown in Fig. 6 (*b*), and this doubles the estimate of M/M_o given by equation (12), for a given value of F/YA_w.

The various theories are compared in Fig. 7, where the two non-dimensional quantities M/M_o and F/YA_w are plotted against each other for the shape of I-section with narrow flanges used in model experiments to be described later, in which $\rho = 3{\cdot}52$. The differences between the estimates of M/M_o in the range $0 \leqslant \frac{F}{YA_w} \leqslant \frac{1}{\sqrt{3}}$ are remarkably small in view of the fact that all the theories are approximate. For example, the maximum difference between M/M_o deduced from Heyman and Dutton's equation (8) and Green's equations (10) and (11) is about $\frac{14}{(1+\rho)}$ per cent., which is negligible for practical purposes unless ρ is exceptionally small (deep web and relatively small flanges).

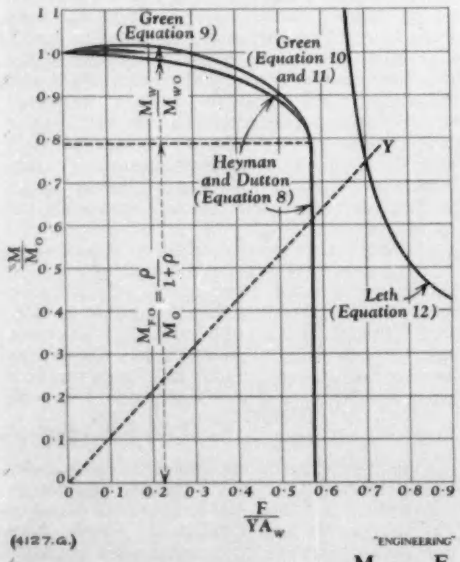

Fig. 7 Theoretical relations between $\frac{M}{M_o}$ and $\frac{F}{YA_w}$ for I-beams with $\rho = 3{\cdot}52$.

The overall theoretical picture is that M/M_o lies within one or two per cent. of unity for F/YA_w up to about $\frac{1}{2\sqrt{3}}$; as F/YA_w increases beyond this value, M/M_o decreases, gradually at first until $\frac{F}{YA_w} = \frac{1}{\sqrt{3}}$, and thereafter rapidly, since the flanges then have to support all the bending moment as well as part of the shear load.

When the shear load is effectively concentrated at a distance l from the support, $M = Fl$ and the corresponding loading line (OY in Fig. 7) is given by the equation

$$\frac{M}{M_o} = \frac{4l}{d(1+\rho)}\left(\frac{F}{YA_w}\right). \quad . \quad (13)$$

This equation enables M/M_o to be expressed in terms of l instead of F if desired. The critical value of l/d below which M/M_o decreases rapidly with decreasing l/d is approximately $\frac{\sqrt{3}\,\rho}{4}$; then $\frac{M}{M_o} \approx \frac{\rho}{(1+\rho)}$ and $\frac{F}{YA_w} = \frac{1}{\sqrt{3}}$. It was suggested by Heyman and Dutton[5] that for the purpose of calculating a conservative estimate of M for values of $\frac{l}{d} < \frac{\sqrt{3}\,\rho}{4}$, $F = \frac{YA_w}{\sqrt{3}}$ should be regarded as the maximum shearing load that a cantilever can support (Fig. 7). It can be seen that for $\frac{F}{YA_w} > \frac{1}{\sqrt{3}}$ there is a large discrepancy between the estimates of M/M_o made by Leth[11] and Heyman and Dutton[5] respectively.

To be continued

PERFORMANCE CHARACTERISTICS OF A 48 INCH WATER TUNNEL

FLOW IMPROVEMENTS WITH A HONEYCOMB

By J. M. Robertson and D. Ross†*

Since the hydrodynamic design of the water tunnel at the Pennsylvania State University was described in ENGINEERING *in* 1948, *it has been completed and testing in it has been active.*

After a brief indication of the tunnel arrangement and operational and special testing features available, this article gives the results of proofing and flow studies. The major conclusion from the studies reported is that a flow-straightening honeycomb is a necessity. The improvement introduced by such a honeycomb, added to the tunnel in the region ahead of the nozzle, is shown to be very significant. With this addition, the tunnel is shown to perform highly satisfactorily. Very uniform flow conditions were obtained in the working section, a low operating cavitation index was found, and the tunnel circuit was so efficient that speeds up to 83 ft. per sec. are possible. In a few respects, the hydrodynamic design of the tunnel is still not optimum. It is shown that the turns do not adequately turn the flow and premature pump cavitation occurs. For some acoustic measurements this cavitation has proved to be a serious disturbance.

The design of the 48 in. water tunnel was described in 1948.[1] It is a closed-circuit, closed-jet, variable-pressure tunnel constructed to permit studies of propeller-body systems under controlled conditions. This tunnel is operated under contract with the Bureau of Ordnance of the United States Department of the Navy by the Ordnance Research Laboratory, a unit of the College of Engineering and Architecture of the Pennsylvania State University. The 48 in. size of the working section was fixed by the choice of an 8 in. diameter model torpedo as the basic test object. Tests were principally to be concerned with propellers operating behind this model, as shown in Fig. 1. This resulted in a tunnel with outside dimensions 98 ft. long by 31 ft. high. The circuit diagram for the tunnel is shown in Fig. 2.

Tunnel Fabrication.—The manner in which the tunnel contours were fabricated is illustrated in Fig. 3, which shows the tunnel shell after it was assembled but before the building in which it is housed was erected. Structurally, the tunnel is basically of welded steel. Certain portions, namely, part of the nozzle, the working section, and the transition section, are large bronze castings with bolted joints. Machined bronze was used in these critical areas because of the need to achieve close dimensional tolerances. In the lower leg of the tunnel the sections at the pump were also assembled with bolted joints for access purposes. The internal steel surface of the tunnel is protected with a vinyl plastics paint. A more detailed description of the tunnel has been given elsewhere.[2]

Accessibility and Controls.—The tunnel size, its accessibility, and some of the auxiliary equipment involved can be seen in Fig. 4, which is an illustration of the exterior of the working section of the tunnel showing the viewing windows and the grating surrounding the access hatch cover at the top of the section. Fig. 4 also gives an idea of the space available around the tunnel in its building. The operating console is located in a glass-walled room and the operators can look directly into the tunnel through the three plastics windows visible in the centre of Fig. 4. All of the controls for changing the tunnel speed*[3] and pressure are located on the console as well as instrumentation indicating water pressure, velocity, temperature, and approximate gas (air) content. Control and indicating apparatus for the motors in the test model are also located on the console. Variation of water temperature and gas content is relatively slow and hence control is effected elsewhere in the building. A 350 ton refrigeration system permits temperature control from 40 to 120 deg. F.[4] Other instrumentation located in the console room is associated with indication of the forces on the test model, the thrust and torque of each of two counter-rotating shafts in the model, and acoustic level indications.

Operating Conditions.—A pressure range of of 3 to 60 lb. per sq. in., abs., was desired as

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* In the design paper a 1,750 h.p. wound-rotor induction motor with a speed range of at least 2 : 1 was indicated, but during the engineering phases of the tunnel design, the power was raised to 2,000 h.p. and a continuously variable-speed motor was chosen. The tunnel is therefore driven by a wound-rotor induction motor which, with the aid of a special control system, gives a speed range of 0 to 180 r.p.m.[2, 3]

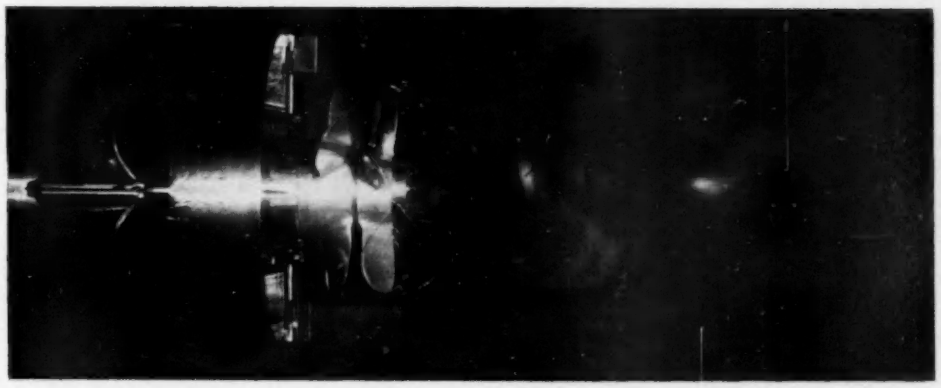

Fig. 1 Cavitation behind a set of counter-rotating propellers fitted to an 8 inch diameter model torpedo, the basic test object used in the Pennsylvania University water tunnel.

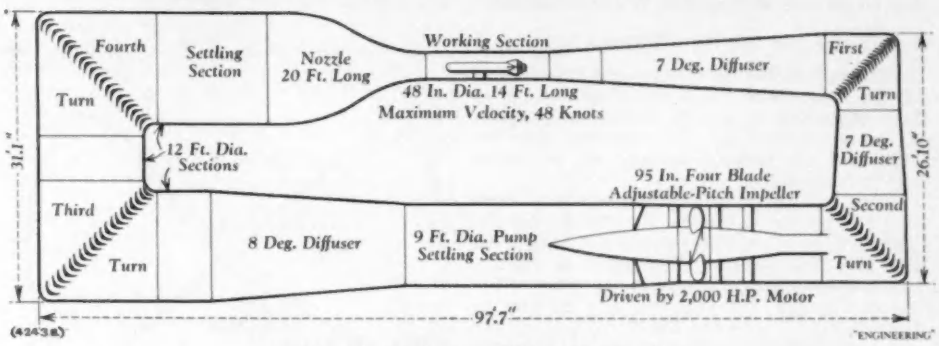

Fig. 2 Circuit diagram of the water tunnel.

well as velocities up to at least 35 knots (60 ft. per sec.), and the tunnel with its auxiliaries were designed to permit independent control of velocity and pressure under these wide ranges. Actually, speeds up to 48 knots (83 ft. per sec.) have been obtained.

The independent control of test variables makes it possible to test a torpedo model over a range of speeds while maintaining the effective depth constant or over a range of pressures at constant speed. The occurrence of cavitation on a propeller can thus be obtained by three different means. It can be obtained by increasing the tunnel speed, by lowering the tunnel pressure, or by varying the propeller revolutions, without any of these appreciably affecting the other two.

Besides the model torpedo for propeller-body tests, means were also supplied for testing free-stream propellers up to 16 or 18 in. in diameter. The tunnel has been used for both types of propeller studies as well as for other research programmes not specifically contemplated in the original design.

Tunnel Use and Proofing.—The tunnel was first operated in March, 1950, and in the first 4½ years of operation over 1,440 test runs (corresponding to some 5,800 hours of operation) were made. During this time it was shut down for operational difficulties, such as minor adjustments on the pump and installation of the honeycomb, for only three months. As a research tool, it has operated with some 65 per cent. of its scheduled one-shift time devoted to research and test work and only about 10 per cent. devoted to maintenance and proofing work. Sufficient time has thus passed since the tunnel was first operated to see how well it functions and to assess the suitability of the design.

The first few months of tunnel operation indicated that, in general, the tunnel was performing according to predictions. The design speed of 60 ft. per sec. was considerably exceeded—a maximum of 83 ft. per sec. being obtained. The pressure-control system worked quite satisfactorily and, as operating techniques were developed, it was found possible to obtain pressures somewhat lower than the planned minimum of 3 lb. per sq. in. abs. However, in the higher speed ranges pump cavitation occurs which, although not serious, is somewhat disturbing to acoustic measurements. During the first year of tunnel operation, detailed studies of the flow indicated certain undesirable features such as rotation and non-uniformity in velocity and pressure, particularly in the working section. This indicated the need for a honeycomb in the settling section preceding the nozzle.

NEED FOR A HONEYCOMB

The function of a honeycomb is to reduce undesirable rotations in the flow. The introduction of a honeycomb in the section preceding the nozzle was considered in the tunnel design, but there was no basis for predicting what rotations might occur. Therefore, the honeycomb was omitted, with the idea that it could be added later if needed.

Evidence of flow rotation and other anomalies was obtained from flow measurements in the tunnel working section and diffuser. The working section contains many piezometer holes and 18 holes (3 in. in diameter) with removable plugs for inserting Pitot tubes, while the rest of the tunnel contains some 75 piezometer holes (the connections to some of which can be seen in Fig. 4) to permit pressure measurement at various points throughout the circuit and some 20 holes (3 in. in diameter) to permit the insertion of Pitot tubes for measuring the velocity distribution at critical stations throughout the tunnel circuit. These were built in the tunnel for the purpose of making the flow studies summarised here.

Working Section.—The tunnel working section is by far the most important part of the tunnel in that all tests are run there. Actually, the major reason for studying the flow in any other part of the tunnel circuit is that it may give an explanation of what is happening in the working section and possibly suggest a cure for any undesirable characteristics. At any cross section in the working section, a uniform velocity distribution is required with no angularity of flow.

The flow angularity measured in the working section before the installation of the honeycomb was as indicated in the two diagrams of Fig. 5. The measurements were made with a 1·9 in. diameter cylindrical Pitot tube projecting across the stream. This Pitot tube had single piezometers at a number of measuring stations along its length. The direction of the flow was found by rotating the Pitot in one direction and then the other until the pressure at any piezometer was the same as that of a reference wall piezometer. The mean of the two angles gave the flow direction at that point. As may be seen, considerable rotation was present, and angularity of as much as 4·5 deg. was indicated. This changed with pump-blade angle and speed. The measurements in Fig. 5 were obtained at a working section speed of 50 ft. per sec., while at 10 ft. per sec. the rotation was in the opposite direction from that shown. Threads or tufts held in the flow also indicated rotation.

Diffuser.—In designing the diffuser portion of the circuit, the idea was to prevent flow separation. If this were done satisfactorily, a good flow would be obtained at the end of the diffuser and it would be quite effective[5]; significant flow asymmetry has however been noted.

Before the installation of the honeycomb, the flow, just upstream of the first turn, was relatively poor. By means of tufts attached to a vertical transverse wire, considerable flow separation was noted in the lower 2 ft. of the section (i.e., near the inside of tunnel circuit). Vertical velocity traverses, shown in Fig. 6, seemed to verify the indication of flow separation, although instrumentation did not permit measurement in the separated region. Considerable circumferential variation in wall pressure at this station was also observed. This amounted to about 14 per cent. of the local average velocity pressure.

The pre-honeycomb flow conditions just before

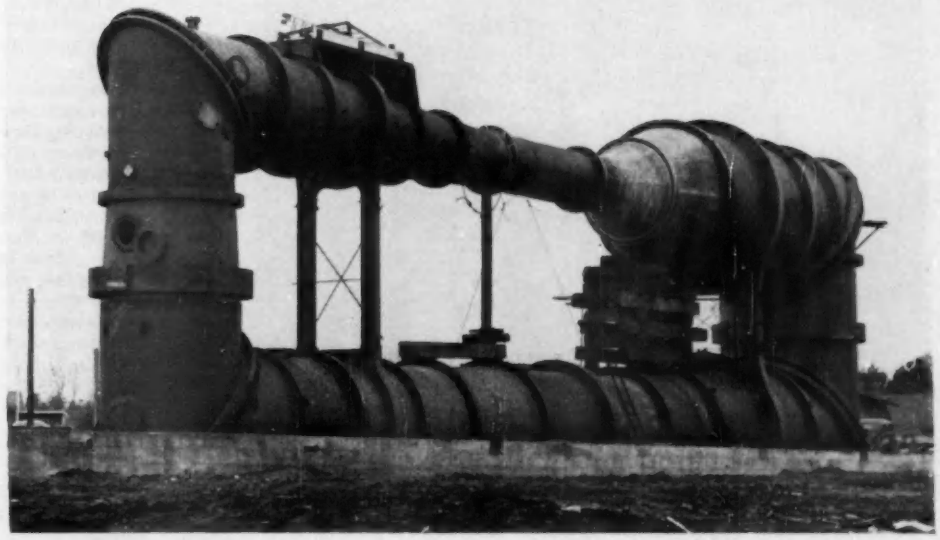

Fig. 3 The assembled tunnel shell before construction of the building which houses it.

the first turn did not specifically point to excessive rotation in the preceding flow. However, the variation with pump blade angle, together with the rotation noted in the working section suggested this cause. The primary evidence of the need for a honeycomb was the relatively poor working-section flow. The honeycomb was installed in the settling section preceding the nozzle in the summer of 1951. This honeycomb of square cells was constructed of 16 gauge stainless steel sheet with a mesh, or spacing of the sheets, of 4 in. and a length of 24 in. Structurally the honeycomb appears quite satisfactory and, as indicated in the following sections, its hydrodynamic performance has greatly improved the tunnel flow.

BENEFICIAL EFFECTS OF HONEYCOMB

Installation of the honeycomb essentially eliminated the flow angularity or rotation in the working section. The thread test showed parallel flow and the measurement of the flow angles with the cylindrical Pitot indicated values less than one degree—less than the inherent errors in the measuring equipment. Other post-honeycomb flow measurements in the working section showed excellent flow conditions, at least to within the precision of the measuring equipment and techniques. A static pressure traverse across the flow made near the start of the section revealed a constant pressure coefficient to within 0·0005 in the core outside of the boundary layer region. Fig. 7 indicates two velocity traverses made at different stations in the working section. In the central core of flow outside the boundary layer, the extreme variation in velocity does not exceed 0·5 per cent. Probably some of this scatter is due to measurement errors.

The installation of the honeycomb considerably improved the flow conditions at the station just before the first turn. The vertical traverses obtained in this condition are shown in Fig. 8 and are seen to have good symmetry. Considerable improvement in the pressure variation about the circumference was also noted. In the post-honeycomb flow studies it was possible to make a horizontal traverse, the results of which are also presented in Fig. 8. Some residual asymmetry as well as a small blade-angle effect is still apparent.

In spite of the asymmetry noted in the horizontal traverse, a fairly good comparison of the measured velocity traverses with those predicted for this station is possible. Two predicted velocity profiles are shown in Fig. 8. The first of these, Method I, is a power-law type of profile[5] while the second, Method II, is a semi-empirical superposition analysis[6] and is seen to give better agreement. Except for the horizontal asymmetry, Fig. 8 indicates excellent agreement between Method II and the measured velocity profiles.

With only slight asymmetry in the diffuser flow, one would expect good diffuser effectiveness.[5] This was found to be so. The diffuser pressure efficiency, which is the ratio of the measured pressure rise to the ideal pressure rise with no losses, was found to be 0·885 just before the first turn. From the diffuser flow studies conducted with the experimental water tunnel, a pressure efficiency of 0·905 was expected. The energy efficiency in the experimental water tunnel studies was found to be essentially constant and to have a value of 95 per cent. From the 48 in. tunnel measurements, this is found to have a value between 96·5 and 97·9 per cent. and to increase slightly with Reynolds number.

OTHER FLOW ANOMALIES

Although, as has been shown, the introduction of the honeycomb vastly improved the tunnel flow conditions in certain critical components, it was not a cure-all. Thus the flow after the turns and the pump behaviour are not completely satisfactory.

Turns.—In the tunnel design, principal attention was placed on the first turn as this has the highest velocity and is in a position to initiate the first flow disturbances. The results of velocity measurements after this turn in the plane of the tunnel loop (i.e., from the inside of the turn to the outside) are shown in Fig. 9. from which it is apparent that the turning vanes are not adequately performing their function. The indications of separated flow along the inside wall show that the turn has changed the flow direction by less than 90 deg. A similar effect was noted in the design flow studies.[7] It is now apparent that inadequate correction was applied to the vane angle of attack.

For part of the location after the first turn, it was possible to utilise a spherical-type Pitot with five piezometers to permit determination of the actual flow direction. The results of the measurements are presented in the upper plot of Fig. 9. The turn is seen to produce a flow angle of 10 deg. thus indicating that the vanes turn the flow 80 deg. rather than 90. At this location no measurements were made before the honeycomb was installed, so it is not possible to assess its affect on this flow anomaly. The extent to which this poor performance of the first turn affects the tunnel flow is difficult to assess. However, as will be noted in the next section, the inflow to the pump is poor and the pump cavitates prematurely.

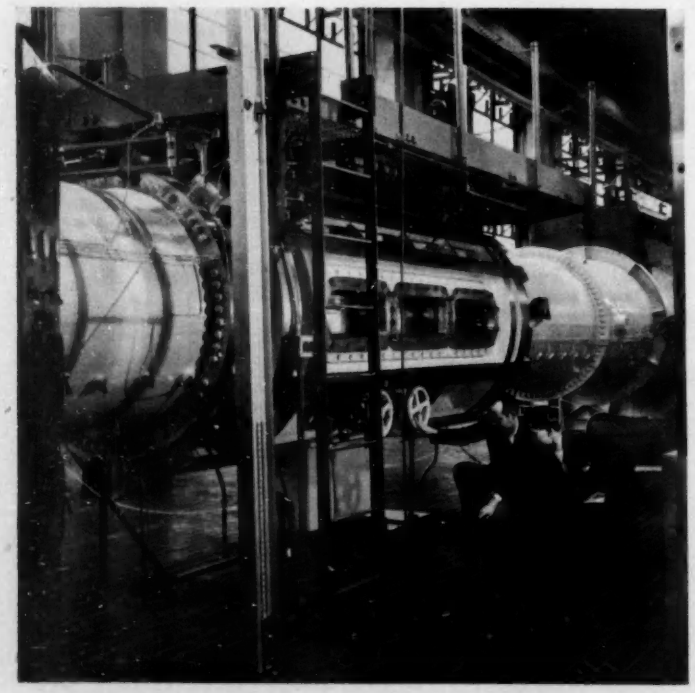

Fig. 4 Tunnel working section, showing instrumentation.

Pump.—The over-all effectiveness of the pump in producing flow through the water tunnel is quite satisfactory. The one phase of pump performance which is not satisfactory is that of cavitation. There is some possibility that this premature cavitation is due to the non-uniform flow conditions preceding the pump. This is one case in which the introduction of the honeycomb has no appreciable effect upon the undesirable conditions.

The flow conditions preceding the pump were measured in the straight conduit between the second turn and the upstream pump straightening vanes. At this station three Pitot tube plugs permitted velocity traverses 120 deg. apart. Wall pressure measurements at this station indicated considerable variation as shown in the upper graph of Fig. 10. The deviations are 0·024 of the working-section velocity pressures or 33 per cent. of the local average velocity pressure. Little change between the pre- and post-honeycomb measurements is evidenced. In the lower part of Fig. 10 the velocity traverses are presented. It is seen that at the upper part of the section (traverse A) the velocity is considerably less than the mean velocity, while at the other two stations it is appreciably greater. Such a velocity defect could contribute to the premature inception of cavitation on the impeller. It is apparent that the honeycomb rectified the discontinuities somewhat and also eliminated a variation with blade angle.

One important item of the tunnel design was the choice of the pump size and speed so as to avoid the occurrence of any cavitation. Here the results obtained are not as satisfactory as could be desired, for at the higher tunnel test speeds impeller cavitation does occur. Cavitation inception measurements indicate that it depends upon the impeller blade angle which is adjustable from angles of -6 to $+22\frac{1}{2}$ deg. For the higher blade angles (15 to $22\frac{1}{2}$ deg.) the critical tip index for the blades is about 2. At lower blade angles, indices as high as $3\frac{1}{2}$ have been measured. Experience with propellers suggests that these are unusually high. If these high values are due to the flow abnormalities ahead of the pump, then remedial measures could be applied to improve the pump cavitation performance.

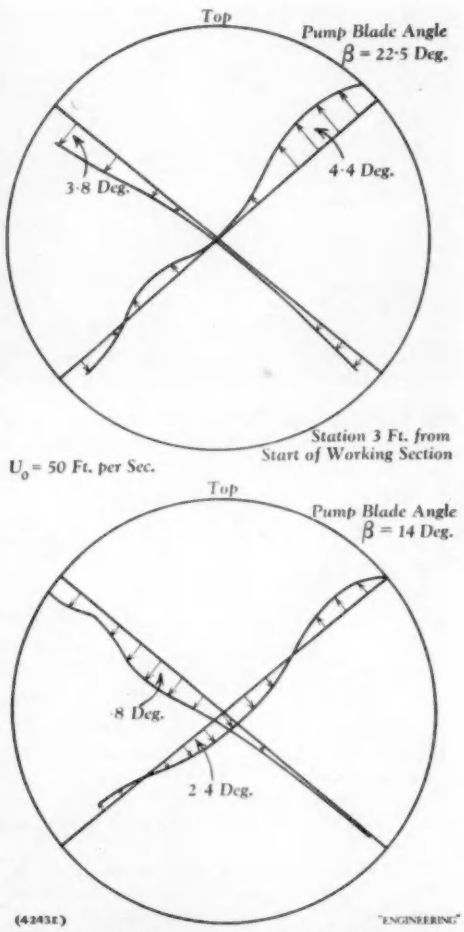

Fig. 5 Angularity of flow in working section before installation of honeycomb, looking in direction of flow.

OTHER FLOW VERIFICATIONS

The flow conditions in many parts of the tunnel were found to be in essential agreement with the design expectations. The introduction

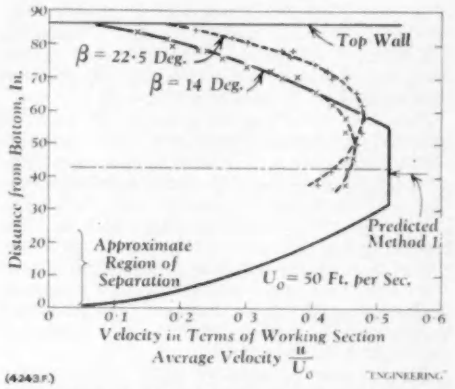

Fig. 6 Velocity distribution just before first turn before installation of honeycomb at two pump-blade angles.

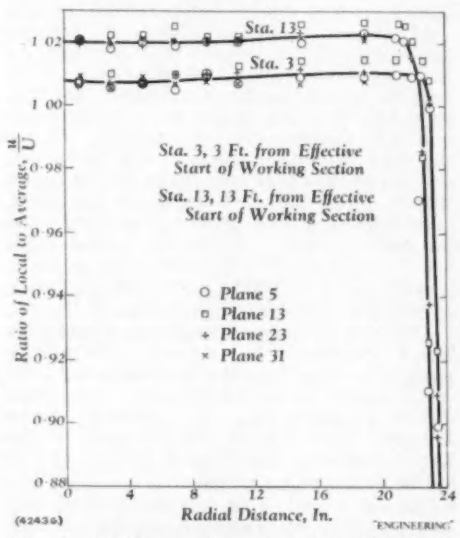

Fig. 7 Working section velocity distribution at two stations.

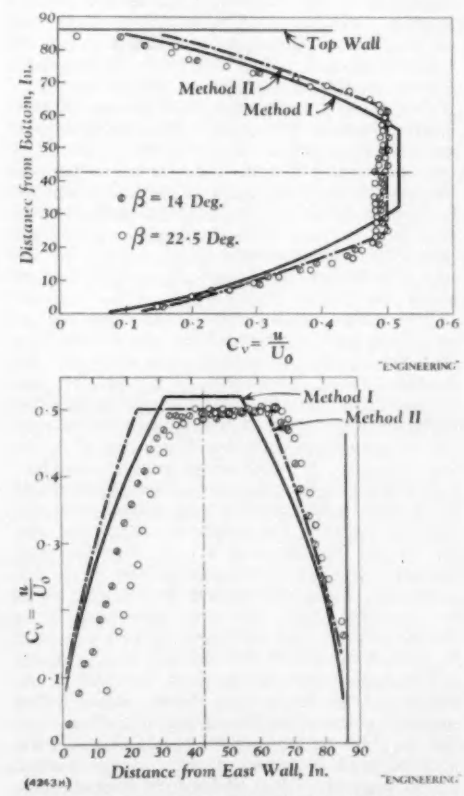

Fig. 8 Velocity distribution just before first turn at two pump-blade angles, after installation of honeycomb.

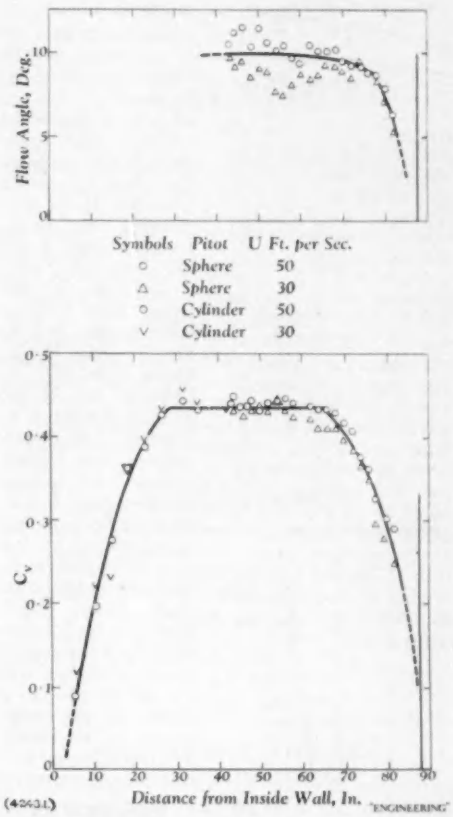

Fig. 9 Measured velocities and flow directions in plane of tunnel at station after first turn.

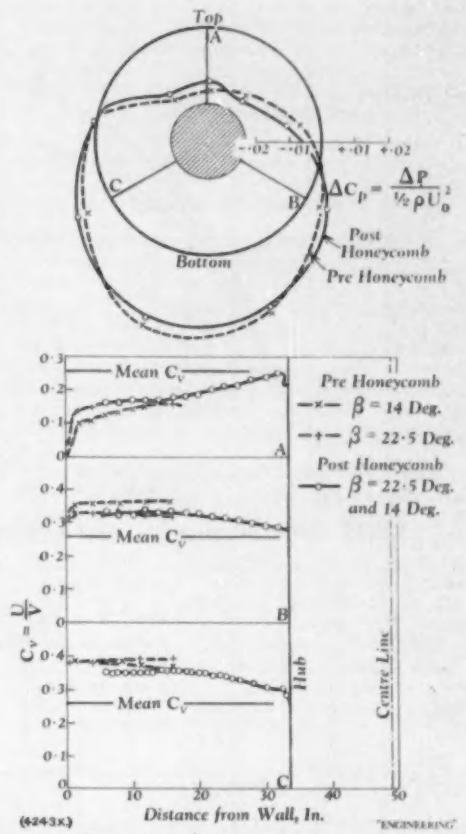

Fig. 10 Wall pressure variation and velocity distribution measured between second turn and circulating pump.

of the honeycomb was found to have little effect on these.

Tunnel Energy Ratio.—A common parameter used to describe the effectiveness of the tunnel design is the energy ratio, i.e. the kinetic energy of the jet in the working section divided by the electrical energy of the driving motor. In the design paper this was conservatively estimated to be 3·8. Actual results found at several pump blade angles are indicated in Fig. 11, from which it is seen that this reaches a value of nearly 6. This, of course, explains why a higher jet speed is obtained than was expected. Eliminating the pump and motor efficiencies, one can define a hydrodynamic energy ratio, i.e. the jet head divided by the pump head, or circuit losses. This is independent of pump blade angle and varies from 5·2 at 10 ft. per sec. to a value of 7 at high rates of flow. Introduction of the honeycomb to the tunnel circuit decreased this ratio by only 4 per cent.

Working Section Pressures.—The longitudinal variation in pressure obtained in the cylindrical working section is shown in Fig. 12. The wall pressures were measured at 14 different stations, each containing 3 to 7 piezometers at different positions around the circumference. The readings at each station have been averaged to give the plotted values. The pressure gradient shown is appreciably less than was predicted during the course of the tunnel design because a conservative approximate method was used for the design. A more refined analysis of the flow in this region has recently been completed,[8] resulting in good agreement.

The variation in the wall pressure near the end of the nozzle and at the start of the transition section is also shown in Fig. 12. Although there is considerable scatter in the individual values, it appears that the design has resulted in a transition section that is close to optimum and in a nozzle pressure dip that is safe from cavitation. In both locations, the pressure variations measured did not differ significantly from those predicted by the design theory.[9]

Turbulence Level.—One final item describing the nature of the flow in the working section is an indication of the turbulence. This was measured with turbulence spheres of ¾ in., 1¼ in. and 2 in. diameter, indicating a turbulence factor of about 1·6. This implies that the turbulence intensity in the working section is generally less than one per cent.

CAVITATION

In a water tunnel the principal concern is in the matter of cavitation. A good tunnel is one that delays as long as possible cavitation effects that would interfere with the tests. The wall pressure measurements in the transition section indicate an inception index for this region of 0·05, a very low value. The cavitation inception index is defined as

$$\sigma_i = \frac{p_i - p_v}{\frac{\rho U^2}{2}}$$

where p_i is the working section absolute pressure at which cavitation starts, p_v is the vapour pressure of the water, U is the mean velocity of the working section, and ρ is the fluid density. Actual studies in the tunnel indicate an inception index considerably higher than 0·05. Offsets were observed in the cylindrical surface of the working section due to windows and hatch cover.* At speeds above 45 ft. per sec. the effect of these offsets was evidenced in a value of the index of 1·1. Early in 1954 particular attention was given to the leading edges of the windows, and the hatch gasket was modified to permit proper seating. These changes reduced the working section cavitation inception index to a value of 0·3 for all speeds. This inception is measured with the acoustic listening gear; lower operating indices are possible for visual observation.

For some tests the operating index is fixed by pump cavitation. As has already been noted, this occurs earlier than had been predicted. The noise from this cavitation is such as to mask some acoustic measurements in spite of the use of a directional transducer for working

* A hatch offset of 0·050 in. due to the gasket was measured.

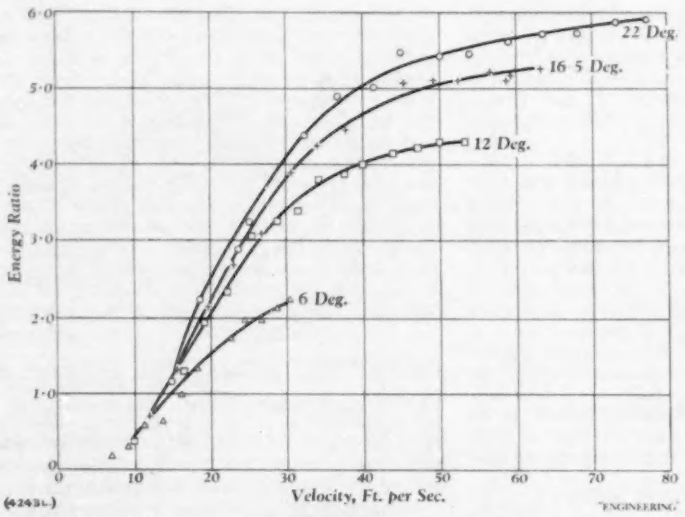

Fig. 11 Water tunnel energy ratio for various pump blade angles.

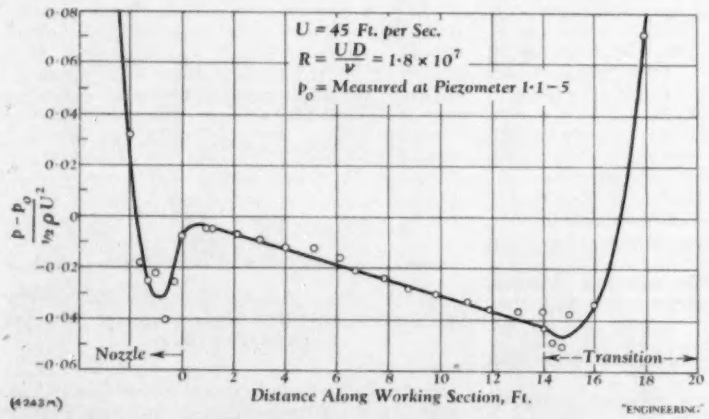

Fig. 12 Wall pressure variation in working section region.

section acoustic measurements. In terms of the working section cavitation index, pump cavitation at the largest blade angle has an inception index of about 0·5 to 0·8 at speeds of 40 to 60 ft. per sec.

Summary.—The water tunnel hydrodynamic design, although quite good, was not perfect. A flow-straightening honeycomb preceding the nozzle was found to be necessary. It is felt by all concerned with the testing and use of this tunnel that our studies have proved the absolute necessity for such a flow-straightening honeycomb. The manner in which this has improved the flow conditions, principally in the working section, has been indicated in this article. It has also been shown that the turn design is not as satisfactory as was expected. This leads to poor flow distribution before the pump, which may explain the premature pump acoustic cavitation.

With the above exceptions, the tunnel has more than lived up to the design predictions. With energy ratios of nearly 6 and working section velocities up to 83 ft. per sec. obtainable, the overall design is quite efficient. The velocity distribution in the working section is quite uniform, with only a thin boundary layer along the wall. Cavitation conditions observed for the working section region indicate critical indices of 0·3. In some cases premature pump cavitation (at working section indices of 0·5 to 0·8) influences acoustic tests.

The tunnel is being used effectively in the propeller design research programme of the Ordnance Research Laboratory, the experimental phase of which programme it was constructed to implement. Besides this, it has been quite useful in aiding other projects of the Navy's Bureau of Ordnance and the Bureau of Aeronautics as well as in research for the Office of Naval Research.

The flow measurements summarised in this article were made by various members of of the staff of the Ordnance Research Laboratory associated with the water tunnel, and the authors acknowledge the help received from Mr. B. W. McCormick, Mr. E. H. Handler, Mr. J. H. McGinley, Mr. E. M. Uram, Mr. J. W. Holl, Miss Frances Rogers, Mr. W. R. Martin, Mr. T. E. Peirce, Mr. G. L. Calehuff, Mr. H. W. Bennett and Mr. A. F. Lehman. The operation of the tunnel, including the various proofing and hydrodynamic flow studies, is supported by the U.S. Navy Bureau of Ordnance under contract NOrd 7958. More detailed information on the tunnel proofing studies will be presented in a report on the water tunnel to be issued by the Ordnance Research Laboratory.

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NEW NAVIGATOR

The only navigational aids for civil aircraft, other than those which depend upon the co-operation of ground-based stations, are still the compass and the sun and stars. In no civil aircraft to-day does the pilot know accurately his ground speed or the wind velocity.

These points serve to underline the importance of a new Doppler Navigator, Type AD.2300, produced by Marconi's Wireless Telegraph Company, Limited, Chelmsford, Essex. Designed for commercial aircraft, it operates independent of ground stations.

Basically, the AD.2300 presents an accurate indication of ground speed and drift. Used in conjunction with a computer it gives an automatic, instantaneous and continuous presentation of the aircraft's latitude and longitude. It can also give distance to go along a leg of a predetermined flight plan; distance to go along a composite desired track to reach a destination; wind direction; wind speed; ground speed and drift angle. All these data can be presented in the form of direct indications on a combined control and indicator unit.

For the pilot's use, a left-right indication for steering the aircraft on a desired rhumb line or great circle track is provided on a deviation indicator. Information of distance to destination and a visual indication when the end of a "leg" has been reached is provided for the pilot.

In addition to these facilities, the left-right course indication is also available as a signal for feeding to an auto-pilot or flight system. Other features include automatic correction for magnetic variation, and provision to change destination or turning points at any time. Should the signal giving the ground speed vector fail, the computation continues—using the last known ground speed and drift angle. In this event, corrections to ground speed and drift angle can be made manually. When the ground speed signal is restored, the equipment automatically resumes. The complete equipment, including antenna and computer, weighs only 130 lb.

Details of the Doppler equipment used by the R.A.F. have recently been released. The military equipment differs from the civil equipment in its use of pulsed waves derived from a magnetron instead of continuous waves derived from a klystron. Both systems measure speed by the Doppler effect. This effect is present when a source of waves is moving.

The waves used in the Doppler navigator are radio waves. Transmitted from the aircraft, they strike the ground and are deflected in various directions, a small portion of the energy returning to the aircraft. Due to the relative motion of the aircraft to the ground the frequency of the return signal differs slightly from the transmitted one. This difference in frequency bears a direct relationship to ground speed.

Additionally, one beam is displaced to starboard and the other to port, the positions being switched alternately. The drift angle is found by comparing the Doppler frequency when the forward beam is displaced to starboard and the backward beam is displaced to port, to the frequency derived when the beam positions are reversed. The antenna is then rotated until the two frequencies are equal. It is then aligned along the aircraft track.

The aerial array consists of four slotted linear arrays lying parallel to one another in a directional horn assembly, the axis of the antenna being horizontal. The forward and backward beams are obtained by feeding from each array in turn; two waveguides being used for transmission and two for reception. The beam width at the half power point is 3½ deg.

A sample of the transmitted signal is extracted in a directional coupler and mixed with the received signal. The resultant is amplified and fed to the receiver over a coaxial cable. The frequency-measuring circuits consist of a discriminator channel in which the Doppler signal is compared with the tone generated by a phonic wheel. The resultant frequency is used to control integrator and azimuth drive circuits.

The integrator circuit controls the speed of the motor which drives the phonic wheel. This speed is a measurement of the aircraft ground speed. The azimuth drive circuit controls the movement of the azimuth drive motor situated in the antenna system and rotates the antennae for drift angle measurement. The resultant speed and drift information are fed by synchros to the electro-mechanical computer.

Marketing

COMMONWEALTH IN DANGER

The Commonwealth Prime Ministers Conference ended on a most cordial note. Yet not even the carefully prepared final communiqué—it took two days to draft—could hide the disappointment which prevailed at the end. Little was done, except to reveal basic and most significant differences in economic interests and political outlook.

The failure of the Commonwealth to supply adequate capital for the many development schemes of its members is probably the most serious. The U.K., which is investing some £150 million a year in the Commonwealth (less than 1 per cent. of national income), " will continue to play its leading rôle in furthering economic development," but the conference recognised that " it is also important to encourage investment from other sources on suitable conditions." This gives a blessing to any member able to raise capital elsewhere on satisfactory terms, e.g., from the United States or the Soviet Union. The other major difficulty —excluding the political differences that have arisen between members, over *apartheid* and " neutrality "—is this country's interest in developing trade with Western Europe. The proposal of the Canadian Prime Minister, Mr. Diefenbaker, for a meeting of the Finance Ministers in Ottawa to draw up plans for the expansion of trade within the Commonwealth and the stimulation of investment is therefore most important.

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Proposed Meeting in Ottawa

The acceptance by the Prime Ministers of Mr. Diefenbaker's proposal for a meeting of the Finance Ministers in Ottawa next September (after attending the World Bank meeting in Washington) means that the need for a carefully planned integration of Commonwealth trade and investment is clearly recognised. But, as Mr. Diefenbaker pointed out, the preparation of such a conference would take at least six to seven months.

One of the major topics for discussion will be the United Kingdom's adherence to the proposed European Free Trade Area. The implications for Commonwealth countries are currently being examined by Commonwealth officials in London. On the whole it is likely that members will give the purpose their blessing and support—in Mr. Diefenbaker's own words, view it " with a benevolent eye "—provided food products are excluded from the agreement. Another will be the implications of the furtherance of free trade by the activities of G.A.T.T. and its successor, the Organisation for Trade Co-operation. It is now unlikely that Imperial Preference will survive, nor, for that matter, is there a very strong case for its survival. Australia's extension of the most-favoured-nation clause to Japan (discussed in a subsequent note on this page) is a clear indication of the conflict which exists between the benefits that arise from Imperial Preference (assured and protected markets) and its disadvantages (high import costs).

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India's Needs

The " enormous difficulties " India is facing in her attempt to fulfil her Five-Year Plan were outlined by the Prime Minister, Mr. Nehru, after the conference. Lack of capital is prejudicing not only the realisation of the plan, but India's whole economic development. On June 12 she exhausted her 200 million dols. standby credit from the International Monetary Fund, drawing the last 72½ million dols., most of which has now been spent. The sterling reserves are pressing hard on the £300 million level, which represents her currency reserves under existing legislation. Mr. Nehru said that a £200 million loan would be " very helpful " in tiding his country over her foreign exchange gap, and negotiations are now in progress in London.

India's need for capital reflects her inability both to save enough to support rapid industrial development and to expand her exports sufficiently to earn the foreign currency she needs for the purchase of plant and machinery. The effects of bad harvests and of the closure of the Suez Canal merely accentuated a basically unsound situation, despite the fact that the level of taxation in India is probably the highest in the world. The policy of banning all but " inescapable " imports is therefore likely to be maintained over the next two years or so. The suppliers of machinery and other essential goods will be vitally affected if not determined by who supplies Mr. Nehru's £200 million. If India's freedom of political decision is to be maintained it is most important that the aid should come from Commonwealth sources.

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Australia-Japan Trade Pact

The signing in Tokio of a trade agreement between Australia and Japan is the beginning of what may prove the gradual disintegration of an elaborately conceived Imperial Preference scheme. The new agreement gives most-favoured-nation facilities to Japanese goods in the Australian market. This does not, of course, mean that the flood gates have been opened. Local industry will require protection, particularly the textile and engineering industries, if they are to survive.

To British exporters, however, the agreement contains a threat of intensified competition from Japan which will be difficult to meet. The Cotton Board's comment that, coming as it does after the Anglo-Australian trade agreement (by which margins of preference can be reduced), the new pact " is a severe blow to Lancashire," will be echoed in many engineering trades. From Australia's point of view it is hardly likely to make easier the resolution of difficulties which have arisen through the loss of valuable frozen beef exports to Britain through increased competition from the Argentine.

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Mission to Canada

The publication of the report on the Canadian market for building materials by a Dollar Exports Council delegation is a hopeful one. It was issued after the delegation, led by Mr. Halford Reddish—chairman and managing director of Rugby Portland Cement—had returned to this country from eastern Canada. They will visit western Canada later this year. Out of their visit, the team have compiled a list of products, ranging from electrical and plumbing fittings to structural components and paints, which they concluded were likely to find a good market over there.

The report emphasises many points already familiar to exporters in the engineering industry. Economic expansion continues at a rapid rate (although building activity this year is lower than last); Canadian domestic production will absorb a large part of expanding demand; imports, 90 per cent. of which are now supplied by American manufacturers, will increase nonetheless; the United Kingdom cannot hope to displace the United States as the major outside supplier, although a larger share of the market would follow an intensification of sales efforts by British manufacturers. There is the usual emphasis on " personal visits by top executives," on the study of Canadian conditions and requirements—" especially as regards climate and building practice "—and on much more forceful advertising.

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Success at the Fair

The enterprise of those companies who have been most active in seeking trade with Eastern Europe during the past few years is being rewarded. The prizes that are being collected after the Poznan Fair are substantial and more are likely to follow. Platt Brothers and Company, one of the constituent companies of Textile Machinery Makers, Limited, announced orders for cotton and worsted machinery from the Polish Government to a value of approximately £1 million.

The United Construction Machinery Company, who are a selling syndicate representing 14 manufacturers of building and constructional plant and equipment, booked orders worth over £100,000. The formation of the company in January this year is an interesting development in co-operative selling in markets where the negotiations are usually conducted with single monopoly buyers. The chairman of U.C.M.C., Mr. W. Muir Robb, commented that a major advantage was to have a director on the spot " with power of attorney authority to sign contracts on behalf of companies in the syndicate."

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Export Drive

The breath-taking efforts of the agricultural machinery makers in export markets continue and gather momentum. The president of the Agricultural Association, Mr. Lionel Harper, announced at the Royal Show, Norwich, that 60 per cent. of the industry's production was currently being exported and that the industry " is launching out even further into the world's markets."

Exports so far this year are substantially in advance of 1956, by 20 per cent. to the end of May, and forecasts for the balance of the year show an even greater increase. The successful removal of the embargo on trade with China—in which the Association played a prominent part —has opened up a vast new market. The industry will be taking advantage of trade fairs, said Mr. Harper, " and all other means at our disposal of bringing our equipment to the attention of the peoples not only of China, but of Malaya, Indo-China, Thailand and the Far East generally.

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Selling to Industry

Considerable emphasis on market research was placed by a study group representing companies in 13 industries whose report has just been published by the British Institute of Management. *Selling to Industry* (5*s*., obtainable from the B.I.M., 80 Fetter-lane, London, E.C.4) concludes that selling goods within industry demands a wider use of market research than it has received. The need is particularly great in finding new markets and new uses for existing products. Considerable advantages can arise by selling to additional industries, and for additional purposes, products that are now sold to only one industry and for one purpose. This can often be done with only slight modifications.

The search for new uses and new markets for existing engineering products has so far been overshadowed by the search for new products. This useful report shows that, with relatively small investment, companies could make more profitable use of their existing ranges of products and in so doing gain valuable time in the promotion of their own growth.

Book Reviews

EARLIEST WRITTEN EVIDENCE

A History of Technology. Vol. II: The Mediterranean Civilisations and the Middle Ages. Edited by CHARLES SINGER, E. J. HOLMYARD, A. R. HALL and TREVOR I. WILLIAMS. *Clarendon Press: Oxford University Press, Amen House, Warwick-square, London, E.C.4.* (168*s.*)

The high standard set by the first volume of this great work, which was reviewed in ENGINEERING, of July 15, 1955 (vol. 180, page 74), has been fully maintained in the second. This is high praise, but the mere expression of such an opinion hardly does justice either to the progressively increasing complexity of the task with which the authors and editors were confronted or their success in its accomplishment. The complexity arises, as the preface indicates, from the fact that, while the material for the first book was derived almost entirely from the results of archaeological excavation, the period covered by the second brings it into the era of written evidence—including in that term the work of artists and other illustrators also.

On a first consideration, this might appear to make the work of compilation easier by removing from it much of the element of pure speculation, but in practice, too often, it merely substitutes one field of speculation for another; it may well be easier to deduce the original form, derivation, purpose, or mode of production of some excavated object than to assess the dependability of some early writer or primitive artist. This problem is more acute, perhaps, with writers than with artists in the inital stages of recorded history, for it is to be feared that some of the writers were being deliberately obscure, whereas the artist was more likely to set down what he saw; his portrayal of it might be deficient in execution and he might omit details of importance, but, generally speaking, he did not give way to sheer imagination. A comparison of some of the illustrations in this book, from very early originals, with the vagueness of some descriptions, roughly contemporary, brings out this point with considerable emphasis. These complications apart, however, there are still the difficulties of deciding the precise interpretations to be put on various words, and, as the preface also observes, of making suitable selections from the vastly greater amount of material that becomes available as the survey progresses into more modern times.

In the present volume, as in its predecessor, the fields covered vary widely in character. The book is divided into five main parts, dealing, respectively, with " Primary Production " (i.e., mining and quarrying, metallurgy, and agricultural implements), " Manufacture," " Material Civilisation," " Transport," and " Practical Mechanics and Chemistry." Each of the five parts is subdivided into a number of specialised sections, so that there are, in all, 21 separate studies, as well as a number of supplementary " Notes," which are really short chapters in themselves, such as those of Mr. Rex Wailes on " Windmills " and Mr. A. G. Drachmann on " Ancient Cranes." In addition, Mr. A. R. Hall has contributed some admirable " Historical Notes " and Dr. Charles Singer an equally admirable concluding survey of " East and West in Retrospect " in pursuance of the declared intention, as set out in the first volume, that the complete work shall be one to appeal to the intelligent reader who is not an expert, without relaxing the standards of accuracy that the expert rightly expects.

One of the principal contributors to Vol. II is Professor R. J. Forbes of the University of Amsterdam. Those who are acquainted with the various excellent books that he has written in recent years on technological subjects (for example, his *Short History of the Art of Distillation*, and *Metallurgy in Antiquity*) will find no less pleasure in reading the chapters for which he has been wholly or partly responsible; they comprise that on " Metallurgy " in Part I, " Food and Drink " in Part II, " Roads and Land Travel " in Part IV (in co-operation with Mr. R. G. Goodchild) and, in Part V, " Power " and " Hydraulic Engineering and Sanitation." One of the illustrations to this last-mentioned chapter, Fig. 620, copied from an engraving by Pieter Brueghel, *c.* 1550, shows a *shaduf*, the familiar water-raising device of Eastern Mediterranean countries, in use on a Flemish farm; but, rather curiously, no mention is made of the fact that it is still to be found on farms in parts of the Netherlands.

It is not possible to discuss in a short review, or even to mention individually, all the scholarly dissertations contained in this volume, but some reference must be made to the section on " Shipbuilding," by Mr. T. C. Lethbridge; notable not only for its concise presentation of the available knowledge on ancient shipwrightry, but for the logical manner in which this regrettably scanty evidence is linked with economic, geographical, and other considerations to form a basis for deductions which, unlike those of some other writers, are agreeably convincing. Mr. Lethbridge does not completely solve the age-old problem of the true meaning of the term " bank " of oars in ancient galleys—an outstanding example of the inadequacy of some written records—but it would have been surprising if he had. To his short bibliography there might be added (though it is not easily come by) John Howell's *Essay on the War-Galleys of the Ancients*, published by Blackwood in Edinburgh and Cadell in London in 1826. It is dedicated to " the Directors of the Edinburgh Academy " and mentions, in the concluding paragraph, that he had built for them a model of a hexireme, or six-banked galley, presumably designed according to the principles he enunciated. It would be interesting to know whether that model still exists.

During the progress of the work on this volume, the editors suffered some regrettable losses among their contributors and other supporters, notably by the deaths of Mr. C. N. Bromehead, of the Geological Museum, author of the chapter on " Mining and Quarrying to the Seventeenth Century," and Dr. F. Sherwood Taylor, Director of the Science Museum, who collaborated with Dr. Singer in writing that on " Pre-Scientific Industrial Chemistry." Both chapters, it goes without saying, are authoritative, erudite and eminently readable. That, however, is true of the whole book. It runs to more than 850 pages, with a coloured frontispiece, 44 Plates, and 695 figures in the text, and there is no part of it that can be safely " skipped " —or, it may be safely asserted, that the reader who has absorbed any single chapter will want to skip. The price may seem high, and, in fact, it is higher than was initially intended, for costs have continued to rise; but the book is still cheap in consideration of all that it contains.

PHYSICS IN PERSPECTIVE

Contemporary Physics. By C. F. VON WEIZSÄCKER and J. JUILFS. *Hutchinson's Scientific and Technical Publications*, 178-202 *Great Portland-street, London, W.*1. (18*s.*)

This book has been translated by Arnold J. Pomerans from a work entitled " Physik der Gegenwart," published in 1952, and the translation is almost consistently good. Its aims, as stated by Professor von Weizsäcker, are to " introduce the educated layman, the sixth-former confronted with a choice of career, and the student of allied fields to the problems of our branch of science." All are praiseworthy and the second is particularly urgent.

Such an undertaking is, however, one of formidable difficulty and one that makes correspondingly exacting demands upon those who can be persuaded to attempt it. Not only must they have an exceptional command of the subject as a whole and a profound appreciation of the significance and interrelation of its component parts, but also they must have the rare gift of presenting the gist of experimental investigations and mathematical arguments in lucid language devoid, as far as may be practicable, of technical terminology. The writings of physicists of the calibre of Bragg, Eddington and Jeans have shown that a few individuals do possess this unusual combination of qualities, and justify the contention that art reveals itself to the greatest advantage when subject to the severest limitations. This little book of von Weizsäcker and Juilfs continues this distinguished tradition.

That the raw materials of physics are neither words nor symbols but observations made under controlled conditions is made clear at the outset by a statement attributed to Faraday: " Physics is to make experiments and to publish them." The major part of the working life of a physicist is spent in a laboratory and the bulk of his work is experimental work, for, as Abraham Cowley remarked shortly after the foundation of the Royal Society, " No man can hope to make himself as rich by stealing out of others' trunks as he might by opening and digging of new mines." Rarely do hitherto untried experiments yield anticipated results and only work in a laboratory can disclose the fundamental perversity of inanimate objects. A collection of experimental findings does not, however, constitute a science until some theoretical interpretation can be found for it. This involves an analysis of the factors concerned to disengage those that are essential from those that can be regarded as accessory; followed, usually, by a reformulation of the simplified situation in mathematical symbolism.

Respect for the traditional divisions of physics that have arisen as a result of its historical development, enables the main stages in the evolution of classical physics to be presented in broad outline in the first half of the book. It has not, however, been allowed to obscure the deeper insight into the mutual relations between the contents of these somewhat arbitrary compartments brought about by the latest acquisitions to our understanding of underlying concepts; the basic duality of particle and wave, is pointed out in the introduction.

A sketch is given, in part I, of the work of the 17th century physicists in laying the foundations of mechanics, while the review of selected topics in mechanics affords an opportunity to describe its more significant subsequent developments. Part II is devoted to heat, to the clarification of the concepts of energy and entropy, and to the connection between heat and atomism, as exemplified by the kinetic theory of gases and by Boltzmann's statistical interpretation of the second law of thermodynamics. In the first section of part III on electricity, magnetism and light, attention is chiefly concentrated on processes in the electromagnetic field and on the electromagnetic spectrum extending from the hardest cosmic radiation to the longest radio waves. Applications cited include radio, radar and phase contrast microscopy. The second section brings us to what is generally classed as modern physics. It contains two chapters, one on electrons with an excursion into election optics, the other on relativity which, by introducing radically new concepts into classical physics, notably enlarged and refined the domain of its validity and led to the mass-energy relation so fundamental in atomic physics.

Part IV, occupying about one third of the text, deals with atomic physics. It begins by tracing the main line of advance from Dalton through radioactivity to quantum mechanics, de Broglie's wave-particle concepts and Heisenberg's uncertainty principle. A list of the elementary particles known at present is given and also

information concerning counter techniques. Following this is a chapter on atomic nuclei and cosmic rays with descriptions of the giant particle accelerators and an account of nuclear fission and chain reactions. The final chapter, on the structure of matter, explains the origin of spectral lines, the determination of crystal structure by X-ray analysis and concludes with a section on biophysics.

This is assuredly a work well calculated to awaken a desire for further reading since, in order to present a coherent outline of the main structure of the subject in so compact a form, much of its detailed content has perforce had to be omitted. These details, fascinating in themselves, can be more surely placed in their proper perspective against a background such as this. In fact the more deeply versed in physics the reader is the better will he be able to appreciate how well and truly the main threads leading from classical to contemporary physics have been sorted out and knitted together in this most vivid and illuminating survey.

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LIMITATIONS ON U.S. EDUCATION

Engineering Enrolment in the United States. Edited by NORMAN N. BARISH. *New York University Press, Washington-square, New York 3, N.Y., U.S.A.* (7.50 dols.)

This book usefully brings together the available information about the growth in the numbers of engineering students in colleges and universities in the United States, the future demand for different kinds of engineer and the prospects of meeting it. Comparisons will inevitably be made with similar projects in this country, though in the book the only country with which a comparison is attempted is Russia.

One of the difficulties of making comparisons is the completely different system of training professional engineers and technicians in the United States and Britain and, in particular, the large number of fairly low-grade degrees granted in the former as well as the lack of the professional examinations of our institutions. Some of the most interesting figures are those of students who fall by the way. Of those who enter engineering schools as freshmen, only just over 60 per cent. last into the senior year and rather less finally obtain their bachelor degrees. These figures are in line with those for students in other faculties of American universities.

There has been a considerable growth in graduate (i.e., post-bachelor degree) study since the war; the numbers enrolled for masters' courses rising from just under 4,000 in the six pre-war years to over 14,000 in the years 1946-52 and over 17,000 in the years 1952-56. For doctors' courses the equivalent numbers were 580, 2,148 and 3,093, respectively. A master's degree is generally considered the equivalent of an honours first degree in Britain.

Emphasis is placed on the need to recruit engineering graduates of superior ability and on the qualitative aspects of educating the types of engineer who are in short supply. There are critical shortages to-day in the United States of research engineers with a high mathematical and scientific orientation and professional engineers with unusual analytic and design creativity. The problem of science teaching in the schools seems, if anything, even more urgent in the United States than it is here. According to the editor of this book only about 27 per cent. of students in the American high schools study algebra; those studying geometry, chemistry and elementary physics are 13, 7 and 4 per cent., respectively. The calibre of teaching is generally too low and for the same reasons as here: the attractions of industry are too great.

In addition to a general survey there are chapters devoted to each specialised branch of engineering and some suggestions for changing the pattern of advanced engineering education in the United States to meet the differing needs of research workers and of design engineers.

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On the Shelf

By Frank H. Smith

The May number of *Mechanical Engineering* (U.S.A.) contains the annual review of heat-transfer literature for 1956. This useful assessment is concluded by a bibliography of just over 200 items divided into 15 sub-headings. It is, unfortunately, one of those bibliographies which give the author and the reference only. The sub-division into detailed subjects, however, does compensate to a great extent for the absence of titles. The same journal contains an interesting article on "Developing Social Awareness in Engineers," so that it would seem that it is not only this country that is concerned at the dangers of an exclusively technical background.

The Advisory Group for Aeronautical Research and Development (AGARD) of the North Atlantic Treaty Organization (NATO), Palais de Chaillot, Paris (16e), is probably little known outside aeronautical circles. Yet it takes a very live interest in documentation (thanks largely to this country's Aeronautical Group of Aslib) and since AGARD is a prolific producer of reports on all sorts of subjects, the documentation group does its share. A recent batch of these consists of Report 47: "Needed Research for Machine Information Systems" by J. W. Kuipers; "Review of Current Machine Systems for Handling Information" by Gwendolyn M. Bedford (No. 46); "Operational Problems Requiring Documentation Research," by Verner W. Clapp (No. 48); "Matching of Operational Languages in Documentary Systems," by R. A. Fairthorne (No. 49); and "Mechanical Storage, Handling, Retrieval and Supply of Information," by R. R. Shaw (No. 50).

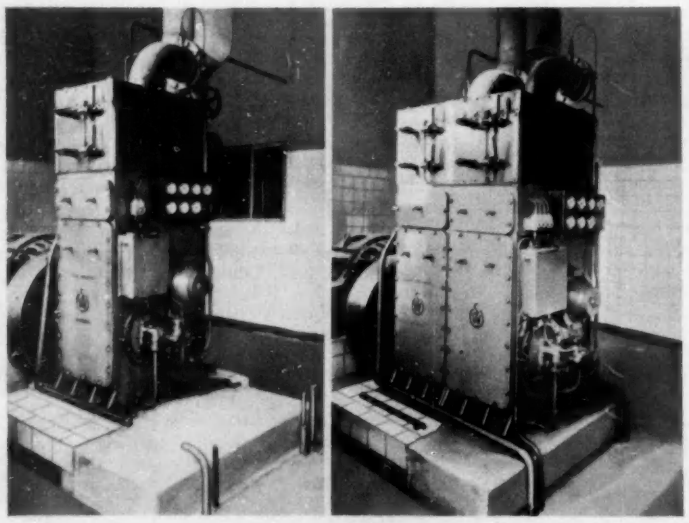
Unesco is undertaking a "long-term programme of studies, experiment and active promotion of developments in new methods and techniques for the communication of knowledge." As a first step, they have published (*Bulletin*, Vol. XII, No. 7, July, 1957), a paper, "New Methods and Techniques for the Communication of Knowledge," by Herbert Coblans, head of the scientific information service of the European Organisation for Nuclear Research. In preparing this paper, he has had the collaboration of Miss Barbara Kyle, who prepared a detailed study which is being published in the *Review of Documentation*. Preprints of both papers are available from Unesco. Coblan's paper carries a 43 item bibliography, the last title of which appeals to me particularly: "A simple method for reducing stocks of publications." I wonder how the two words "burn them" can be expanded into a paper?

Ladsirlac is a portmanteau initial word which stands for Liverpool and District Scientific, Industrial and Research Library Advisory Council, and I find it difficult to decide whether the initials are preferable to the cumbersome title. However, *Ladsirlac Information Publication* No. 1 is entirely commendable. Published by the Liverpool Central Public Libraries at 2*s.*, it is the text of a lecture given last October by A. M. Bennett, M.I.N.A., M.I.Mech.E., M.I.Mar.E., on "Fires in Cargo Ships." But I do feel that a paper of this nature would be better placed in the publications of either the Institution of Naval Architects or the Institute of Marine Engineers. This is another instance of the paper-scattering which I deplore.

The Society of Naval Architects and Marine Engineers (74 Trinity-place, New York), is publishing (Volume 1, No. 1, April) the *Journal of Ship Research*. For these days of high specialisation, this strikes me as being a rather loose title but perhaps it has been chosen deliberately. Both theory and practical experiment are covered in the articles of the first number. In January, 1947, the Society started a programme of research and has now realised that its work should be shared by a larger audience. Contributions are invited from any persons feeling that they have something to offer. Single copies of the journal cost 2 dols.; a year's subscription is 6 dols.

There are some firms in America who specialise in reprints, not only of books (such as Dover), but also of whole runs of periodicals. They are expensive, of course, but I suppose there are libraries which start with an unlimited budget and to whom the possession of a "run" is more important than counting the cost. The Johnson Reprint Corporation, 111 Fifth-avenue, New York 3, have just issued a 15 page booklet listing such runs as *Zeitschrift für angewandte Mathematik und Mechanik*, Volumes 1–20, at £160 15*s.*—or a single volume at £7 3*s.* Another little bargain is *Engineering Index* (not to be confused with ENGINEERING Index) for 1928–1949. This is a mere £500 (singles at £25). The London agents are: Academic Books, Limited, 129 Queensway, W.2.

Longmans, Green and Company, Limited, 6/7 Clifford-street, W.1, have produced an interesting and useful catalogue, "Engineering Books." This lists autumn publications of Longmans and of Prentice-Hall and also the latter house's April books.



The basic unit of the Spilling engine is a single-cylinder machine built from standard parts. Other similar units can be added, as required, to make a multi-cylinder engine.

A NEW APPROACH TO STEAM ENGINE DESIGN

Unit Construction and Interchangeable Working Parts

It is sometimes thought that the reciprocating steam engine reached its final stage of development many years ago, and that it is now obsolete. Neither impression is correct. Under certain conditions the steam engine is more than capable of holding its own against other prime movers.

An important development in reciprocating steam engine design in recent years, widely used in Germany, the country of its origin, but not, perhaps, so well known here, is the Spilling unit-construction system. Made by Spillingwerk, G.m.b.H., Werftstrasse 5, Hamburg, 11, Germany, the Spilling " steam motor " incorporates several novel features, the most important of which are full interchangeability of working parts, and unit construction, which enables engines to be built up from standard units to the size and power required. Engines can also be increased in power *in situ* by adding extra cylinder units, or changed to suit different steam conditions by replacing the appropriate parts. The Spilling engine is a high-speed machine, which gives it a large power output for a relatively small size, and it has been specially designed to overcome one of the normal concomitants of high speed—heavy wear. All rotating and sliding parts are pressure lubricated, the hydrodynamic effect taking care of the bearings, while in the case of the pistons and cylinders wear is kept to a minimum by low mean speeds. Strokes are short—2¾ in. to 5½ in., according to the size of the unit, and the mean piston speeds are in the range 11·5 ft. to 13·75 ft. per second.

ENGINE BLOCK UNITS

Basically the Spilling steam motor is a totally-enclosed, single-cylinder steam engine, with piston valve gear. This is the basic, or engine block, unit. The crankcase is arranged to carry cylinders of different bores and strokes, but of uniform outside and fixing dimensions. Other single-cylinder units can be bolted to the first one to build up a multi-cylinder engine. Only a new crankshaft is needed in addition to the new cylinder or cylinders; all the parts of the first cylinder remain in service.

The piston is a hollow steel member with an interchangeable cast iron jacket carrying the rings in the normal manner. It works in a cylinder having an interchangeable liner. Each cylinder is bolted direct to the crankcase, and has no connection with the other cylinders of a multi-unit engine. A replaceable cross-head and guide are provided for the lower end of the piston rod, and there is telescopic sealing between the crankcase and the cylinder block.

Similar sealing is provided on the valve rod, which is driven by a contra-rotating eccentric shaft, geared to the crankshaft. The steam passages in the cylinder block are dead straight and very short, and the interchangeable cross-head guide is so designed that this desirable steam passage feature can be maintained for different cylinder diameters, while retaining the standard eccentric shaft. Individual adjustment of each eccentric enables the steam distribution to be arranged as required in each cylinder of a multi-unit engine. The eccentric shaft drives the governor, which can be of various types, according to requirements. It is characteristic of the engine that governing is to close limits; the method of governing, like the other elements of the unit, can be chosen to suit a particular application, and changed at a later date if necessary.

FEW BASIC COMPONENTS

Only two types of unit or engine block are made; the small unit, of 2¾ in. stroke, and the large unit, which is in two variants, 5 in. and 5½ in. stroke. The small unit runs at 1,500 r.p.m. normal speed, and gives up to 40 effective b.h.p. per cylinder. A maximum of five of these small cylinders can be connected to form a single engine. The 5½ in. stroke engine has a normal speed of 750 r.p.m., and a maximum output of 160 b.h.p. per cylinder, five units being the limit for a multi-cylinder arrangement. From the 5 in. stroke engine a maximum of 200 b.h.p. per cylinder, at 1,000 r.p.m., can be obtained, and six units can be coupled together.

From these basic units any engine within the range can be built up, and it can be altered at any time to meet changed requirements. Accessibility of all parts is good, and the changeover from one set of steam or power characteristics to another, or the replacement of worn parts with new ones, can be done quickly with normal fitter's tools.

The engine has many applications, the commonest of which is as a back-pressure engine suppiying process steam and coupled to an electric generator, or else driving production machinery direct. On such installations low fuel costs are possible; typical figures claimed are 0·44 lb. of hard coal or 0·31 lb. of fuel oil per kWh. If steam is available from waste heat, or from cheap fuel, the engine is again applicable, and in all cases its simplicity and long life, well-known characteristics of the steam engine, are of value.

Finally, it should be added that the engine can be adapted for various special steam conditions when necessary. It can, for example, be run as a condensing engine, with compounding, and one or more cylinders against vacuum. There are examples of engines having been installed to work in this way and then, as process steam demands increased, having been converted to work against back pressure.

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VERSATILE AIR CONTROLS

A new film, " Air Controlled," produced for Benton and Stone, Limited, Aston Brook-street, Birmingham, 6, had its first showing recently. Illustrating the use of compressed air equipment made by Benton and Stone and their associates Geo. H. Hughes, Limited, the film ranges widely over many different applications, from simple clamping, component ejection and swarf blowing, to process control and complete mechanical handling schemes. It shows, too, the versatility of the equipment in respect of operating conditions, examples being given of its use in the ideally clean surroundings of a large dairy, and in a slag-processing plant, as well as in many ordinary engineering shops.

A booklet is available to accompany the film, and to provide in handy form illustrations of many of the applications shown. Numerous circuit diagrams are also given in the booklet. The film, of 16 mm. in colour, and with a spoken commentary, is available on loan from Benton and Stone, Limited.

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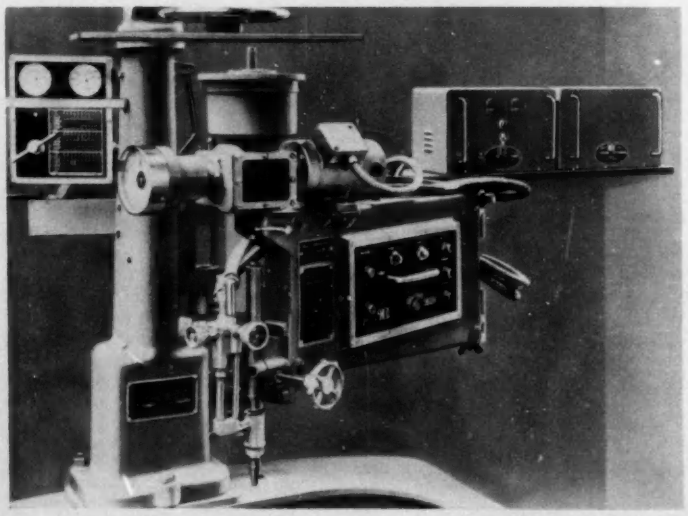
COMPUTER-CONTROLLED FLAME CUTTING

Ferranti Limited, Hollinwood, Lancashire, and the British Oxygen Company, Limited, Bridgewater House, Cleveland-row, St. James's, London, S.W.1, have announced that they have been co-operating for the past twelve months on research in the field of computer-controlled flame cutting machines. As well as fully automatic operation of the profiling process, the system includes automatic control of the gas supplies and cutter head rotation. It is believed that the system could be used to increase the productivity of the shipbuilding industry. Demonstrations of the first experimental machine are expected to take place in the autumn of this year.



The thyratron control unit (right) is used to control accurately the rate of cut of the universal flame cutting machine.

An electronic control unit has recently been introduced by British Oxygen Gases Limited. The illustration shows it attached to their 36 in. universal cutting machine. Known as thyratron control, the unit enables the machine to be pre-set to an accurate cutting speed. It virtually eliminates the speed variations caused by mains voltage fluctuations.

BORING A CULVERT

Recently demonstrated at Staines was a machine for driving holes for culverts or pipelines, of a type that has had considerable application in laying petroleum pipes in the United States. The great advantage claimed is that there is no need to disturb the ground surface, that being of particular import in this case when the tunnel has to pass under a main railway line and a road. The main contractors for the drainage work at Staines are Willment Brothers, Limited, Baltic Wharf, Waterloo Bridge, London, S.E.1, and the machine is operated by Costain-John Brown, Limited, 73, South Audley-street, London, W.1.

Rotary-head soil boring machine in which the spoil is removed to the rear by an internal helical screw.

The actual cutting is carried out by a rotary head with radial sets of teeth, the whole being slightly larger in diameter than the tubular casing which follows it. Within this casing is a helical screw which rotates with the cutting head and so removes the spoil to the rear. Head and casing are drawn forward by a winch and pulley. The power unit, consisting of a 50 h.p. International Harvester Diesel engine, together with the associated gearboxes and clutches, is saddle mounted on the casing. At the front end is the winch for moving the whole assembly forward, and the thrust is taken by gusset plates welded on to the casing. A square socket, chain driven from the reduction gearbox at between 50 and 60 r.p.m., slips over the free end of the screw shaft and through this transmits the drive to the cutting head. As tunnelling progresses additional lengths of casing are welded on to the earlier lengths together with conveyor screw extensions. The normal limit is about 200 ft.

A pit is first dug to the required depth, and made as long as circumstances permit. Length is an advantage as it enables longer extension pieces to be used and so cuts down the number of welds and resettings of the power unit. At the bottom of the pit are laid rails which afford a guide to the direction of boring. In any event, the natural tendency of the machine is to follow a straight line, but deviations can occur as a result of meeting strata of varying hardness, or other obstructions. The rate of drilling naturally depends on the material involved, but speeds of about 1 ft. in two or three minutes are usual for pipes up to 42 in. in diameter. The spoil is shovelled away as it falls from the rear of the casing. At Staines, the handling of casing extensions and of the machine itself, which weighs 6,100 lb. and was made by M. J. Crose Manufacturing Company, Limited, Tulsa, Oklahoma, U.S.A., is carried out by a D.7 Caterpillar tractor fitted with a side boom. When it is not desired to use guide rails, boring can be carried out with the machine slung from the boom.

THE HOT-BLAST CUPOLA AS AN ECONOMIC UNIT

In order to meet the requirements of the iron foundry of Dobson & Barlow, Limited, Bolton, Lancashire, in the production of castings to B.S. 1452, grade 12, for the textile and general engineering industries, a hot-blast cupola plant was installed some 21 months ago and the experience gained in its operation formed the subject of a paper presented by Mr. J. Henderson, on June 20, during the 54th annual conference of the Institute of British Foundrymen at Harrogate. The author stated that the weekly output of from 150 to 160 tons of castings covered a very wide range, varying, in weight, from ounces to 2 tons and, in section thickness, from $\frac{1}{8}$ in. to 4 in.

Designed to give a nominal melting rate of from 4 to 8 tons per hour, the two cupolas installed were identical and operated on alternate shifts. The sole-plates were 7 ft. above ground level to allow for the installation of a 4 ton capacity electrically tilted hot-metal receiver of "teapot-spout" design. Blast was introduced into the cupola by six water-cooled tuyeres operating at a diameter of 4 in. and protruding 3 in. into the melting zone, which was 42 in. in internal diameter. From the melting zone to the charging sill the stack was a parallel shell 60 in. in external diameter. Iron bricks extending 5 ft. 3 in. down from the charging door minimised damage caused by falling charges. The stack was unusually high, namely 23 ft. 6 in. from the tuyeres to the charging sill. This additional height allowed the gas offtakes to be positioned at a sufficient height above the tuyeres to allow comparatively cool gases to be drawn off, while, at the same time, a sufficient height of stock could be maintained above the offtakes to prevent the ingress of air into the recuperative system. Furthermore, the maximum amount of sensible heat was transferred from the gases to the charges before these gases were removed.

Water at the rate of 7,000 gallons an hour was used for shell cooling and at 3,000 gallons an hour for tuyere cooling. The average increase in the temperature of the water was 30 deg. F., and the calculated heat loss 12 per cent. of the heat available in the coke. The essential features of the recuperative hot-blast system were a high-level stack gas offtake, a separate combustion chamber, a recuperator with horizontal cast-steel and cast-iron tubes, and a waste-gas recirculation system. The recuperator was cleaned with compressed air but it had been designed to be equipped with mechanical shot cleaning, when required. Four gas burners having flame-failure equipment preheated the combustion chamber so that melting could start with a blast temperature of between 350 and 370 deg. C., thus ensuring stable conditions immediately melting commenced. Cold blast was supplied to the recuperator by one of a pair of fans capable of delivering 5,000 cub. ft. per minute at a water pressure of 60 in.

In the author's opinion, the plant had fully justified itself, in that all the expected benefits had been realised. Compared with the procedure previously in vogue, the cost of the metal at the spout had been reduced and an all-scrap charge could be successfully melted.

The full water-cooling of the melting zone had resulted in a saving in refractory and in the labour involved in effecting cupola repairs. An overall saving of 30 per cent. in labour requirements had been made, and an increased production of moulds had followed the increased melting capacity.

The control over the cupola was more consistent; increased control over carbon and sulphur content had been obtained, while silicon could be controlled within satisfactory limits.

A continuous supply of high-temperature metal was available. Increased production had resulted from the uninterrupted supply of iron from "first tap" to "blast off." Shut-downs for such purposes as tuyere cleaning and the removal of slag pots were unnecessary.

Four additional benefits had also resulted, namely, unexpected advantages in founding properties; increased life of ladles on account of the temperature and the cleanliness of the iron; a reduction of "pour-down" resulting in the melting of less iron to produce a given tonnage of castings; and extreme flexibility of the melting unit, melting rates of from $3\frac{1}{2}$ to $6\frac{3}{4}$ tons an hour being obtained without alteration to the cupola diameter.

Based on market prices ruling in April, 1956, the saving on material costs per ton net of good castings, using the hot-blast plant in 1956, was £4·975, compared with the cold-blast plant of 1954. The yield of net good castings had increased by 7·1 per cent. In addition, the saving in refractories was about £1,000 per annum, while a saving of £500 per annum was given by the reduced consumption of charcoal used to retain the fluidity of the slag in the slagging box. The saving in labour amounted to about 150 man-hours a week, the only overtime required being on Saturday to clean the recuperator and the combustion chamber.

After allowing for capital depreciation and the maintenance costs that inevitably would be incurred in the future, it was considered that an adequate return was being obtained.

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HIGH-SPEED FLIGHT FILMS

The Shell Film Unit have recently shown the first of a series of three educational colour-sound films on high-speed flight that they are preparing. Part I—"Approaching the Speed of Sound"—describes how sound travels through air and how the speed of sound affects high-speed flight, and the effects of various design features. The effects of airflow over wing sections and aircraft models in a wind tunnel are depicted by colour Schlieren photography, using green as the background colour; regions where the air density is rising show up as red, and where it is falling, as blue.

The film is available on loan, free of charge, to responsible organisation and clubs, from the Petroleum Films Bureau, 29 New Bond-street, London, W.1.

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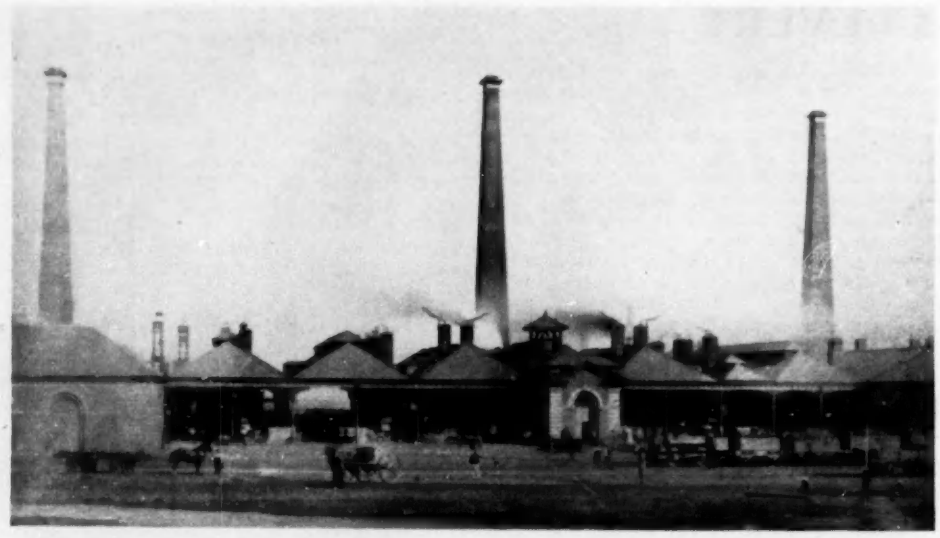
ANTI-SUBMARINE HELICOPTER

Westland Aircraft Limited, Yeovil, have delivered the first helicopter to be built in Britain specifically for submarine warfare—the Mark VII Whirlwind. The first were delivered to the helicopter flight of No. 700 squadron of the Royal Navy, where they will undergo intensive proving trials.



Substantial buildings and a spacious planned layout were characteristics of the Round Oak works when laid down a century ago.

STEEL FROM THE BLACK COUNTRY

From Wrought Iron to Tube Billets

To have existed successfully for a hundred years is in itself a creditable achievement, but Round Oak Steelworks, Brierley Hill, Staffordshire, the centenary of which was celebrated recently, have more claims to fame than that of mere age. A century ago the Black Country, of which Brierley Hill is a part, had just about reached its zenith as a producer of pig and wrought iron, and it was as a finished iron works that Round Oak came into being. They were a logical addition to the industrial concerns operated by the family of Ward, from whom the present Earl of Dudley is descended. The very extensive Ward mineral properties produced coal, ironstone, limestone and sand, and the family had blast furnaces in operation on the property. The Round Oak Ironworks, as they were originally, were designed to use pig iron from the adjacent Level New Furnaces, and to produce the highest grades of wrought iron. The family connection remained right up to nationalisation.

To say that the works were "designed" to make wrought iron is to use the word in its literal sense, and to draw attention to a distinctive feature of Round Oak. Many ironworks existed in the Black Country at that time, but most were small and all had grown rather than been developed. There was little sign of planning in the average local ironworks at the time. Round Oak, on the other hand, resulted from planning as a homogeneous whole, with 28 puddling furnaces, forge and rolling mills housed in a large building, 480 ft. long and 138 ft. wide. This was divided into three parts, the puddling furnaces and forge being in the centre, 21 in. plate and 16 in. bar mills at one end, and 12 in. bar, 8 in. guide and 7 in. wire mills at the other. Standard gauge railway track connected one section with another, and with the other family industrial properties via the private line known as the Pensnett Railway, a concern some years older than the ironworks.

Incidentally, it is worthy of note that the Pensnett track crossed the line chosen for the old Oxford, Worcester and Wolverhampton Railway, and that when the latter was built, in 1852, the Pensnett made a level crossing with it. To-day, the Pensnett still crosses, on the level, the main line of the successor to the O. W. W. R., the Western Region of British Railways, so providing a rare example of a private line running on the level over a public main line. Traffic, which is considerable, is controlled from a Western Region signal box, the Pensnett locomotives signalling by whistle when they require passage; this is granted only when the W. R. line is clear, the W.R. trains taking precedence.

STEAM FROM "WASTE" COAL

Round Oak Ironworks, which employed some 600 men, were constructed on the most liberal lines, with the best available machinery, the object being to produce a superior grade of wrought iron. In this they soon succeeded, and for as long as iron was made at Round Oak, the brand LWR-O commanded a higher price than practically all its competitors. The plant, of course, was entirely steam driven, and it is a commentary on the times that it was hardly considered necessary to raise steam by waste heat. A little of the steam needed was generated in this way; most of it came from cylindrical egg-ended boilers fired on coal slack. Steam demands would be quite heavy, too, especially as the plant included such equipment as a circular saw in the 16 in. mill driven by what an account of 1860 calls a "rotary emission engine," or in other words, a Hero aeolipyle or whirling sphere. It should be added that these elementary reaction turbines (for such they were), were not uncommon for driving high-speed saws in ironworks, and if they were, as the local phrase has it "steam eaters," it mattered little when coal slack, on the evidence of many contemporary accounts, was virtually unsaleable and in effect a waste product.

IMPACT OF STEEL

The ironworks were extended from time to time, and by 1882, there were 40 puddling furnaces, but nothing of special importance occurred until 1890, when a start was made in the erection of steel plant. It was, of course, bowing to the inevitable. There had been warnings, even when Round Oak works were being built, of what the future was to bring, for it was in 1856 that Bessemer read his celebrated paper to the British Association, but cheap steel was not to become a reality until quite a few years later. By 1890, the open hearth furnace had been tried and proved, and it was with three 17 ton open-hearth furnaces that Round Oak made its first steel. New rolling-mill equipment, a 30 in. cogging mill and a 28 in. finishing mill dealt with the output of the furnaces. From that time onwards, steel was in the ascendency at Round Oak; wrought iron was still made for some years, but it was gradually superseded.

At the outbreak of the 1939–45 war, the works had two melting shops, one with five basic open-hearth furnaces each of 50 to 60 tons capacity, while the other housed two 90 ton tilting furnaces. The 36 in. cogging mill was capable of rolling 4,000 tons of ingots a week, and the remainder of the mills, a 30 in. billet, a 28 in. finishing, a 12 in. three-high, and an 8 in. three-high, rolled the products in which the Company, by then bearing its present name of Round Oak Steelworks, Limited, was specialising. Angles, channels, joists, tees, rounds, squares, flats, billets and blooms (the largest range of any Black Country works), were rolled in mild steel and certain other grades of steel as well.

EXPANSION AND DEVELOPMENT

At the end of the war, Round Oak, in common with other British steelworks, started a large programme of expansion. In some ways history has repeated itself. The original works were based on local conditions at the time, and were planned to make use of the local pig-iron supplies. The present works have been designed to use the large quantities of steel and iron scrap which the great engineering industries of the neighbourhood provide. The original ironworks justified themselves in a few years; the present steelworks have more than justified themselves already, and the work of expansion is still going on.

The core of the immediate post-war development was a new melting shop, 685 ft. long, and containing five open-hearth furnaces, each of 100 tons nominal capacity. They are gas-fired, from a battery of Morgan gas producers, and have Spencer-Bonecourt waste-heat boilers, which provide all the steam needed by the gas producers. The make of the furnaces for the year 1956 was 317,760 tons.

To deal with the output of this shop there is a new 37 in. cogging mill, driven by an electric motor of 4,000/12,000 h.p., capable of rolling ingots up to 4 tons 15 cwt. each in weight. A two-stand, two-high, reversing 28 in. mill, driven by a 4,000 h.p. motor, rolls all the heavier sections such as channels, joists, angles and rounds. A 30 in. mill, similar in design to the

Development continues. In this aerial view, which shows about half the works, the new melting shop is in the foreground. Older plant, since dismantled, is at the rear.

28 in., rolls solid sections, such as rounds, squares and tube squares.

MODERNISATION PROCEEDS

The new melting shop and mills were in production by the time of the next change in the history of the works. In 1953, the works were de-nationalised, and sold to Tube Investments Limited. Since the new owners took over, large sums of money have been spent on developments, and a further £2½ million are committed. The most important feature of the new development programme is the provision of two 50 ton electric-arc furnaces. These furnaces are now being built, and when they are in production the ingot capacity will rise to about 500,000 tons a year.

It is fitting that the centenary of Round Oak should coincide with a large development plan. The original works were put down to serve the demands of the time; they were successful because they gave the customer what he wanted. Needs and methods have changed and are changing, and Round Oak Steelworks are changing with them.

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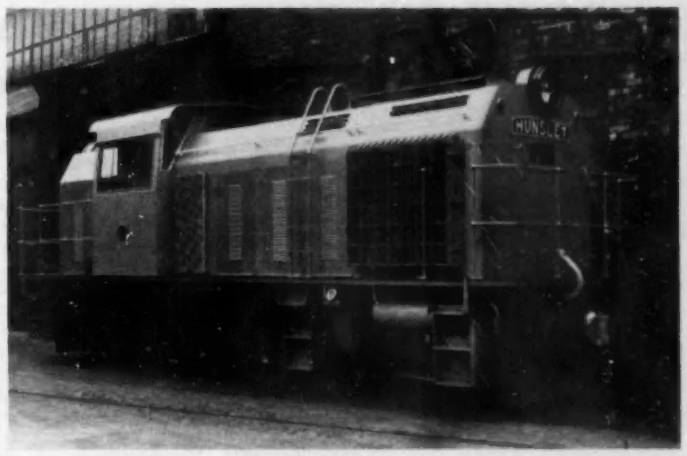
AUTOMATIC SPOT WELDING

A resistance welding machine with an indexing head was shown at the recent Electrical Engineers' Exhibition. The machine, designed and manufactured by Hirst Electronic, Limited, Gatwick-road, Crawley, Sussex, is for use in automatic production lines for spot or projection welding both ferrous or non-ferrous components. It is particularly intended for welding small components, such as silvered contacts for switchgear to their brass and copper backing strips.

The motive power for revolving the table and depressing the welding head is compressed air, and outlets are available for loading and unloading devices. The table illustrated has six positions, and delivers one component every four seconds, but this can be altered to suit requirements. The welding head is air-operated and water-cooled, but is of low inertia enabling short welding times down to 5 milliseconds to be used. The timing control for the welding current is synchronous controlled between ½ and 9 cycles and is switched by an ignitron contactor. The capacity of the machine is 75 kVA. It was shown at the exhibition fitted with a monitoring device which can be used to ensure that every weld receives a quantity of welding current between certain chosen limits. Welds falling outside those limits would be rejected.

Compressed air operates both the indexing table and the welding head of the automatic welder.

This 3 ft. 6 in. gauge locomotive for use at high altitudes employs torque converter transmission.



DIESEL-HYDRAULIC SHUNTING LOCOMOTIVE

For use on the 3 ft. 6 in. gauge railway in the Mufulira copper mines in Northern Rhodesia, the Hunslet Engine Company, Limited, 125 Jack-lane, Leeds, 10, have constructed the 637 h.p. 0-8-0 type Diesel-hydraulic locomotive shown in the illustration.

It has a weight in working order of 56 tons and a maximum axle load of 14½ tons. Maximum tractive effort is 38,000 lb. with a top track speed of slightly under 13 m.p.h. The locomotive is 34 ft. 8 in. long over the automatic couplers, with an overall height of 12 ft. 6 in. and an overall width of 9 ft. The coupled wheel base is 13 ft. 6 in.

Power is provided by a 562 h.p. Paxman 12 RPHL Series II Diesel engine developing 440 h.p. at 1,250 r.p.m. under the site conditions of 4,000 feet altitude and temperature of 95 deg. F. A separate Diesel engine is incorporated for driving the auxiliaries, this engine being a 75 h.p. Ruston 4YEL developing 60 b.h.p. at 1,500 r.p.m. under the site conditions.

Transmission from the main engine is by universal shaft drive to the Hunslet converter box, followed by a Hunslet multi-plate friction clutch coupling the drive to the input shaft of the main gearbox. The final drive is taken from the gearbox jackshaft by coupling rods to the wheels. The gearbox is a Hunslet two-speed constant-mesh totally enclosed box giving speeds of 7·96 and 12·83 m.p.h. in either direction of travel. An automatic gear change based on pre-selection and governors is fitted, providing the locomotive with single lever speed control, a separate lever being used to engage forward or reverse direction.

The auxiliary engine is mounted in the front casing compartment, the drive again being by multi-plate friction clutch and flexible coupling to the auxiliary gearbox, from which drives are taken to two compressors, the generator, an exhauster, and the radiator fans. This auxiliary gearbox also carries a flexibly mounted starting dog which is engaged with a similar dog mounted on the free end of the main engine crankshaft for starting the main engine.

Two main radiators of the sectional type with Serck elements are fitted. They provide water and oil cooling for the main and auxiliary engines, oil from the torque converter unit being cooled by means of a separate radiator.

The large totally enclosed cab has two rear doors approached from either side of the locomotive, and has a wood inner roof, sliding and fixed windows providing all-round vision, upholstered swivel seats, a large toolbox, steel cab floor, and a three-speed electric fan mounted at the front of the cab roof. The controls are duplicated on each side of the cab, and the instrument desk, containing all necessary switches, oil and water gauges, etc., is situated between the two driving positions.

Westinghouse straight air brakes and a screw-type hand brake are fitted for locomotive braking, and vacuum braking is provided for the train, arranged so that the brakes can be applied together or independently. Visco-Alliance couplers and coupler operating gear are fitted at each end of the locomotive.

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LEVEL LUFFING CRANES

The first of two new level-luffing cranes has been built by Babcock and Wilcox Limited, Linton House, 7–12 Tavistock-square, London, W.C.2, for Beck and Pollitzer Limited, of Bankside, London. The particular attributes claimed for these cranes are their high output, simple operation and easy maintenance.

Many standard principles of design are incorporated, but welding has been extensively used in the manufacture of the pedestal, the tubular jib and lever. Balancing and luffing gear has been simplified and an independent centrally positioned driver's cabin, with an armchair control unit, has been incorporated. Level luffing is still achieved by the swan neck supported on fixed guide ropes. Both jib and lever are of tubular construction and balance of the jib is provided by a connecting link on each side of the counter-balance drive, thereby reducing the number of fulcrums employed.

The armchair control unit has been supplied by Allen West and Company, Limited, Brighton, 7. The drum controllers are mounted horizontally, and are easily accessible for maintenance. Slewing is by a separate motor, driven through a Fluidrive coupling. The capacity of these cranes is rated as 1¼ tons.

In this crane, welding has been extensively used in both jib and pedestal.

REJUVENATING OLD MACHINES

PNEUMATIC RAMS REDUCE COSTS

In 1953, Fredk. Braby and Company, Limited, brought together in a new steel fabrication factory at Crayford, Kent, the resources of two works at Deptford and one works in the Euston-road, London. The Euston-road factory had entered the field of "perforated metals" in the late Nineteenth Century, and nine of their original power presses dating from 1883 to 1910 are still in operation. These machines have been improved mechanically during the last 50 years by the addition of refinements as machine design has developed, and have given years of excellent service.

In many cases, however, this has resulted in machine controls becoming cumbersome to operate, with a multiplicity of levers, requiring a high degree of skill in the operation to co-ordinate the control movements correctly. Nevertheless, the machines were well liked by the production department; they compared favourably with some of the more recently acquired machinery from the point of view of trouble-free running and replacements. Accessibility and, therefore, ease of tool changing is far greater on these older machines, which makes them more suitable for small batch work. In those days machines were built to last, with massive frames and generous bearing surfaces—characteristics which will probably again receive emphasis in the machinery of the future, designed for automation.

Rather than scrap their well-tried machinery, therefore, Fredk. Braby have found that the use of compressed-air equipment affords a straightforward and very economical means of mechanising the control gear, simplifying it and in some cases increasing the machine output. The system components are supplied by the Baldwin Instrument Company, Limited, Dartford, Kent. A description of Baldwin industrial pneumatics was given in the June 25, 1954, issue of ENGINEERING, and it may be recalled that the principal features of this equipment are standardisation of components and rugged construction to stand up to heavy usage with the minimum of servicing.

Many of the old power presses in use at Braby's works have heavy fly-wheels which have to be brought to rest when it is desired to change a tool or insert a sheet. This operation required some judgement by the operator in order to bring the flywheel at rest with the press hammer at the top of its stroke. With the fitting of a pedal-operated pneumatically actuated brake, as shown in Fig. 1, this operation is accomplished within one revolution of the flywheel, and is completely foolproof. The overall cost of the modification was of the order of £100 or less.

The press on which this particular air brake was fitted dates from 1883, is known as "Jumbo," and is used for producing closely-pitched rows of perforations in steel plates. The feed is automatic. Jumbo, a fairly complex piece of machinery from the operator's point of view, has been the subject of extensive modifications. Simplification of the machine controls has enabled the strokes per minute of the hammer to be increased by approximately 15 per cent., which compares very favourably with contemporary German perforating presses that Braby have installed since their move to Crayford.

Hitherto, Jumbo was the responsibility of a specially-trained operator, but since the mechanisation of the controls it can now be operated by anyone on the shop floor. The hammer which impresses the perforating tool is linked to the driving connecting rods by means of dogs. In order to insert a fresh steel plate in the machine, it is necessary to hold the hammer in its topmost position, by means of catches. In the days when the machine was manually controlled, the operator, when starting up, had to manipulate three levers almost simultaneously—one controlling the catches securing the hammer, one controlling the dogs engaging the drive, and one controlling the feed; if he was not sufficiently dexterous, the machine would jam. To-day a single lever operating a pneumatic valve brings about these operations; the hammer retaining catches are actuated by means of a 1½ in. pneumatic cylinder and ram seen at the top of Fig. 2, and the drive dogs are engaged by a 1½ in. cylinder mounted on the hammer itself. Speed regulators are incorporated in the control valve. A small pilot valve, actuated by a cam once every crankshaft revolution, acts as a topping-up device to the two main cylinders to conserve air. A second lever actuates the 3 in. braking cylinder.

Other uses to which Braby have already applied compressed air are pneumatic clamps in guillotines and shears and automatic press guards interlocked with the actuating mechanism. A good example is shown in Fig. 3; this machine, originally a hand-bending machine, for which the firm had no further use, is now adapted as a marking machine for producing inch-spaced indentations on channel guide rail. The machine has been stiffened at the ends and spanned by a beam on which is mounted the cylinder and ram for actuating the press. A counterbalanced guard has been fitted, and the lowering of the guard trips the plunger of the pilot valve causing air to be admitted to the operating cylinder.

The first machine to be modified by the addition of a pneumatic ram has now been in operation for three years, with no trouble to report—the synthetic rubber oil seals are still fully efficient, and as yet Braby have discovered no need for spare parts.

Fig. 1 Heavy flywheels, hitherto taking 4 to 5 minutes to run down, are brought to rest in seconds with an air-operated brake.

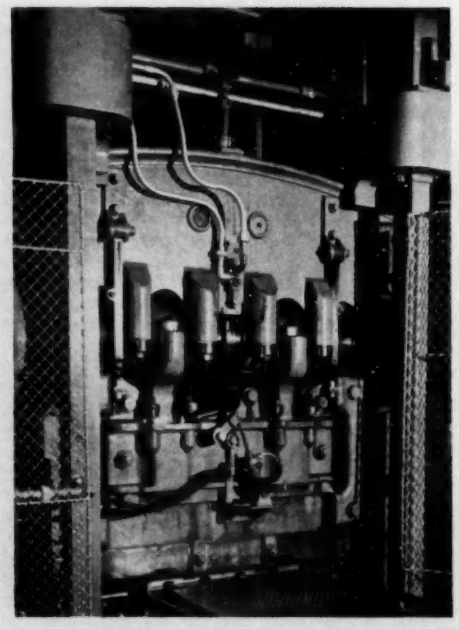

Fig. 2 Control of this 1883 perforating press has been completely mechanised by pneumatics and can now be worked by unskilled labour.

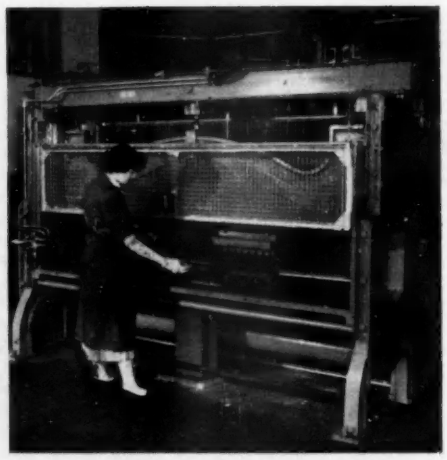

Fig. 3 This marking machine, originally a hand bending machine, is automatically actuated by lowering the press guard.

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RAILWAY ROLLER BEARINGS

The two "Talisman" trains introduced on the King's Cross/Edinburgh run with the summer timetable have both been fitted with roller-bearing axleboxes throughout. This has been done with the intention of operating the trains on a double trip of 786 miles per day. The bearings have been manufactured by British Timken Limited, Duston, Northamptonshire.

At present each of the trains is made up of British Railways standard coaches together with open seconds, a twin-articulated dining set (used at one time on the "Coronation" trains), and a kitchen car of Eastern and North Eastern Region design. The standard coaches have British Railways bogies, while the articulated set and the kitchen car have E. and N.E. heavy type bogies and the open seconds have light type bogies. All three types have different arrangements of axlebox guides and spring gear.

A single design of tapered roller bearing axlebox was produced by Timken, working in collaboration with the design staff of the Carriage and Wagon Engineer, North Eastern Region. This design is basically common to all three bogies. A common journal size of 4½ in. diameter was agreed, and existing wheel sets had their journals turned down to take the roller bearings. A standard dimension of 8¾ in. across the guides was agreed since this matched with the existing dimension on the plain bearing boxes. The changeover was made progressively, the bogies equipped with plain bearings being withdrawn from service in turn.

The bearing is a dual race type having a 2½ in. diameter bore and an outside diameter of 7$\frac{15}{16}$ in. The axlebox body is in cast steel to B.S. 592, Grade C. A lime base grease will be used for the bearings, and it is anticipated that the sets will run for long periods.

PLASTICS ON VIEW

Concluding its 10 day run at Olympia to-morrow, July 20, the British Plastics Exhibition this year demonstrates the increasing infiltration of plastics into industrial and domestic life, with over 250 firms showing raw materials, plant and equipment, and finished products—about twice the number that took part in the 1955 exhibition. This year for the first time overseas exhibitors were invited and there are some 40 participants from Belgium, France, Germany, Holland, Italy, Sweden, Switzerland and the United States. Concurrently with the exhibition has been running a convention—also international in character—on plastics technology, covering the polyolefins, polythene, polyvinyl chloride, the extrusion process, injection moulding, material developments, and glass-reinforced plastics. The organisers of the Exhibition and Convention are the journal *British Plastics*, in co-operation with the British Plastics Federation. We propose in this brief note on the exhibition to confine ourselves mainly to a few applications of plastics in industry.

REINFORCED PLASTICS

One of the speakers at the convention (Mr. W. A. Baker, Bristol Aircraft, Limited), predicts that, now that a background of research data, design experience and the "know-how" to control manufacture to produce consistent products are being built up, the reinforced plastics industry is on the eve of expansion into a wide range of engineering applications where other materials have previously held pride of place. Bristol Aircraft have themselves had in production for some time now asbestos-reinforced phenolic-resin drop tanks, and they are showing examples of such tanks for the Hunter, Sea Hawk (Fig. 1), and Venom aircraft, as well as a glass-reinforced high-pressure storage vessel, and a high-speed radar scanner, in asbestos-phenolic-resin, to very close dimensional tolerances.

Although this article does not set out to cover generally plant and equipment for making plastics, it does seem opportune here to refer to the spraying process for glass fibre-reinforced synthetic resins, introduced by M.A.S. Kunststoff-Vertrieb G.m.b.H., Düsseldorf, and demonstrated by their United Kingdom agents, Metropolitan Plastics, Limited, Glenville-grove, Deptford, London, S.E.8. It would appear that this process should contribute effectively to the desired consistency of the product, as well as reducing costs by the elimination of skilled manual labour. The equipment enables cut lengths of glass fibres and resin to be sprayed evenly and in any desired proportion, and is suitable for handling unsaturated polyester resins, phenolics, melamine and epoxy resins.

An application of reinforced plastics to aircraft uses which seems likely to go into large-scale production is a glass-fibre-reinforced double passenger seat shown by Microcell Limited, Imperial Buildings, 56 Kingsway, London, W.C.2. In comparison with contemporary metal seats of similar design, the fibreglass seat weighs some 15 lb. less which, it is estimated could represent a gain in revenue of some £45,000 per annum per 100 seat airliner.

Two other structural reinforced glass exhibits by Microcell are a liquid storage tank, built up from standard panels 4 ft. by 4 ft. bolted together, with a strip of sealing material between panels, very light in weight and suitable for storing corrosive liquids as well as for use as water tanks; and the "hose-ramp" illustrated in Fig. 2, designed to protect exposed piping, up to 6 in. in diameter, by providing a bridge that can carry vehicles weighing up to 10 tons. It consists of a series of interlocking mouldings, and being readily portable, it can be carried as part of the normal equipment of, for instance, a fire engine.

EXPANDED PLASTICS

The use of glass-reinforced plastics for the hulls of boats is now thoroughly established and many examples are on view at the exhibition. A simple plastics hull, still in the experimental stages, which is expected to lead to the development of an unsinkable lifeboat, is on view on the stand of Whiffen and Sons, Limited, Fison House, 95 Wigmore-street, London, W.1. This structure derives its light weight from the use of Whiffen's new Fi-Vi expanded unplasticised P.V.C. sheet laminated with resin-bonded glass fibres. The experimental hull has already proved to be unsinkable with a 4 in. diameter hole exposed in its bottom, and with three people on board.

Fi-Vi is also an excellent heat and vibration insulant, and is likely to find applications in the building trades. A number of other expanded plastics for weight-saving and buoyancy applications, thermal and sound insulation, are also on view at Olympia, generally of the polystyrene and polyurethane types.

PLASTICS SHUTTERING

Polystyrene, increasingly used in the refrigeration industry both in its expanded form and as vacuum formed sheet material, is now entering the civil engineering field as a shuttering material. Toughened polystyrene sheet, extruded from Lustrex T6 (a product of Monsanto Chemicals, Limited, Monsanto House, 10–18, Victoria-street, London, S.W.1), has been vacuum-formed as moulds for casting the concrete blocks forming the walls of the Bristol Corporation's Barton Hill Flats. It is claimed that moulds of this type eliminate the irregularities that occur with wooden formwork, and that a controlled surface finish and design features can be readily incorporated.

HIGH-STRENGTH FILMS

Among the plastics films, now available, the polyester films, based on the same basic polymer as Terylene, are outstanding for toughness and high strength, as may be appreciated from Fig. 3, which shows a 3 ton boiler being supported by several thicknesses of 0·001 in. Melinex film. The makers, Imperial Chemical Industries, Limited, Imperial Chemical House, Millbank, London, S.W.1, have announced that Melinex film is now becoming available in quantity. The tensile strength of Melinex is 27,000 lb. per sq. in., and it has a high impact resistance and good tear strength. These properties, combined with great transparency, make it an ideal packaging material. Its resistance, to abrasion has led to its use, in metalised form, for kick-panels in automobiles. It has a low permeability to gases and moistures, and is resistant to oils, fats, solvents, and corrosive substances. It is therefore useful as a hose lining for pipelines carrying gases and corrosive chemicals. The material is also an excellent electrical insulator.

Here we must conclude this fractional survey of the 1957 British Plastics Exhibition, well aware that we have not touched upon many important plastics developments such as the increasing use of the resistant properties of plastics in the chemical industries, and notably the possibilities of p.t.f.e., only now at the beginning of its exploitation; the possibilities of flame-spraying nylon and polythene protective coatings; the silent-running self-lubricating properties of phenolic-resin bonded and nylon gearing; the advantages of polythene piping for plumbing systems—now available with all-polythene jointings; and the ever increasing uses of plastics by the electrical world

Fig. 1 Sea Hawk drop tanks in asbestos-phenolic plastics. Bristol Aircraft Ltd.

Fig. 2 The glass-fibre reinforced hose-ramp provides a bridge, protecting hoses and cables laid on the ground, capable of carrying 10 ton vehicles. Microcell Ltd.

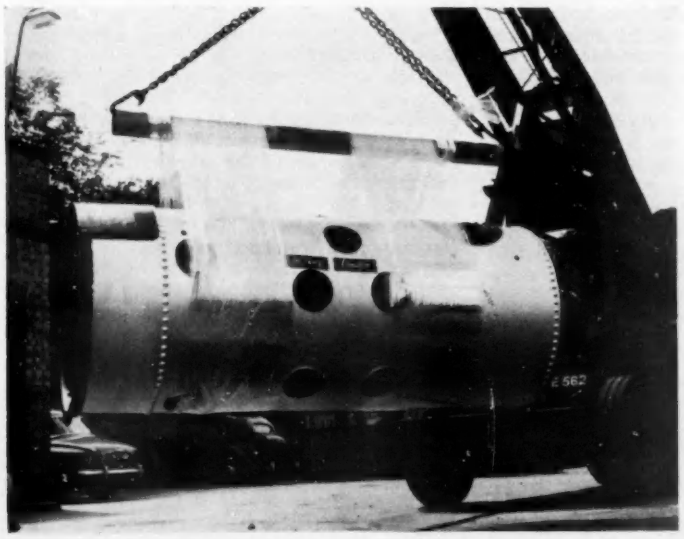


Fig. 3 The high strength of Melinex polyester film (intended primarily for the packaging and electrical industries) is demonstrated: several thicknesses of 0·001 in. Melinex support a 3 ton boiler. Imperial Chemical Industries.

ATOMIC REVIEW

More Materials

LAST week Atomic Review was devoted largely to topics associated with materials. Other aspects of the same subject are treated this week, beginning with a series of reports on eight papers presented at a conference on "Materials for Nuclear Engineering," organised by the Physical Society, 1 Lowther-gardens, Prince Consort-road, London, S.W.7. The conference was held at the research laboratory, Associated Electrical Industries Limited, Aldermaston Court, Aldermaston, Berkshire, on July 11 and 12.

Effects in Solids of Nuclear Gas

Many materials undergo nuclear reactions when irradiated with neutrons, some of the products being the normally gaseous elements, usually the rare gases helium, xenon, or krypton. The formation of these gases within a material can cause drastic structural changes affecting the design of a reactor in which such a material is used.

The brittle naturally-occurring mineral thorianite contains both uranium and thorium, which produce helium by natural radio-active decay. If this mineral is geologically old it will contain large quantities of helium. Upon slowly heating such a mineral, it fragments explosively at about 950 deg. C., helium being released in the process. Similarly boron and also boron carbide, both of which are brittle, fragment upon irradiation with thermal neutrons, there being a helium-producing reaction in boron. It is thought that in each of these materials the included gas diffuses to flaws, building up a gas pressure, which causes crack propagation resulting in the fragmentation of the mineral.

The behaviour of deformable materials containing gas is quite different from that of brittle materials. Beryllium produces helium and tritrium during bombardment with fast neutrons. As, however, the cross-section for the reaction is low, a long time is needed for the production of an appreciable quantity of gas. To avoid this lengthy irradiation, beryllium cyclotron targets which have been bombarded with 40 MeV alpha-particles have been examined. Large quantities of helium can be injected into these targets in relatively short bombardment times. It was found that after heating the targets, a large number of small "bubbles" appeared lying in a band at the end of the alpha-particle track. Heating near the melting point reduced the number of bubbles, their size increasing.

Uranium atoms undergo fission during bombardment with thermal neutrons, and the rare gases xenon and krypton are among the products. Upon heating uranium which has been irradiated at less than 200 deg. C., a large number of very small internal bubbles form and the material increases in volume. Extensive experiments in which the volume increase of such uranium has been measured under various temperatures and pressures have confirmed the view that these bubbles contain the major portion of the gas formed during the irradiation. If the uranium is irradiated while at high temperature, the gas precipitates in a few large bubbles resulting in a large increase in volume. Irradiated uranium also shows a tendency to crack. ("Structural Effects in Solids of Nuclear Induced Gas": Dr. R. S. Barnes and Dr. A. T. Churchman.)

Plutonium Metal

There are two features of the metal plutonium which make its study distinctive; firstly its radioactive toxicity and secondly the diversity of allotropic forms which it exhibits. Considerable precautions have to be taken to protect workers on plutonium, and in order to keep laboratory air plutonium-free all work is carried out in specially designed glove boxes. It is inevitable that the adoption of these techniques slows up substantially the rate of progress, but a feature of the equipment developed is its flexibility and simplicity.

Five allotropic forms of plutonium were identified in 1944 in America and in 1951 in this country, and when very high-purity plutonium was prepared in 1953, a sixth phase, delta-prime, was identified.

The dilatometric study of plutonium established at an early date the large volume changes involved, in which expansions at lower temperatures give place to contractions at high temperatures. Of fundamental interest is the negative coefficient of expansion in the face-centred-cubic delta phase. This behaviour is unique for a metal having an isotropic crystal structure and emphasises the abnormal behaviour of the plutonium atom.

The specific heat of plutonium and its neighbours has been determined at the A.E.R.E. as 0·036 0·0025 calories per gramme per deg. C., by simple calorimetry, over the range 25 to 80 deg. C. This corresponds to an atomic heat, $Cv = 7{\cdot}6$ calories per mole per deg. C., for plutonium, which compares with a value of $Cv = 6{\cdot}6$ for uranium.

The high degree of allotropy means that the effect of alloying elements on the stability of the various phases is of considerable interest. It is now known that, in general, the delta-phase shows the strongest tendency of all the phases to form solid solutions. In the zirconium system, currently under study at the A.E.R.E., the solid solution in δ-plutonium extends to about 60 per cent. zirconium. It is also an interesting fact that plutonium dissolves up to at least 10 per cent. in the α-zirconium structure, with a slight depression of the α/β zirconium transition. It also forms a compact $PuZr_2$ with hexagonal cell similar to that prepared for UZr_2.

At the A.E.R.E., and the A.W.R.E., there is a continuing programme of experiments designed to afford fundamental information. The same might be said of the workers in Los Alamos Laboratory, New Mexico. The French workers at Chatillon are beginning to do valuable work and some experiments of fundamental importance may be expected to come from laboratories under construction at Dounreay. Chalk River, Canada, have found out some very interesting facts about a variety of alloys and information of the same kind as provided at Dounreay should come from the Argonne National Laboratory.

Apart from facilities in the western world, there has been one paper published in Moscow and later at Geneva which showed that a substantial amount of work had been done in the Soviet Union. ("The Physical Properties and Alloying Behaviour of Plutonium Metal": Dr. M. B. Waldron, Metallurgy Division, A.E.R.E., Harwell.)

Ductility of Beryllium

Beryllium is a metal of attractive nuclear and high-temperature properties, for which there is an increased present demand for reactor purposes. Limited application as moderator and reflector has been achieved in America and (it is believed) in Russia. Fuel canning and structural component applications, as intended in the United Kingdom, have been precluded so far, primarily by the relatively low ductility of the metal. This factor is also responsible for the main development difficulties of fabrication and joining.

Pure beryllium has not been prepared, so that its ductility is still open to conjecture. Analogy with titanium and zirconium, as well as other considerations, strongly suggest embrittlement by interstitial impurity atoms, causing lattice distortion and inhibiting slip and twinning.

There are two approaches to the ductility problem—one via metal physics, and the second via purification. In America, recent single-crystal study has explained certain property anomalies of commercial-purity beryllium. In addition, the fabrication control of preferred grain orientation has resulted in the preparation of sheet of high two-way ductility, and of up to 40 per cent. elongation. A similar attempt at the improvement of the transverse ductility of beryllium tube has not been made. Equal success in metal joining is necessary for the ultimate canning application of satisfactory sheet or tube.

Despite the many difficulties involved, there is considered to be sufficient justification for a final attempt at the preparation and property evaluation of pure beryllium with a view, if necessary, to its subsequent commercial production. ("The Ductility Problem of Reactor Beryllium": Mr. G. C. Ellis, Atomic Weapons Research Establishment, Aldermaston, Berkshire.)

Irradiation Effects in Graphite

The explosure of graphite to radiation, certainly at temperatures below 200 deg. C., and probably at temperatures of up to 1,000 deg. C. at least, has a profound effect on its physical properties. Apparently all the physical properties are affected except the colour of the material, which remains black. The change in physical properties is chiefly dependent on the flux of particles and, in reactors, this means a flux of neutrons.

After irradiation, the damage consists of vacant lattice sites and interstitial atoms but the annealing of graphite after a cold irradiation tends to restore its physical properties. The eventual tendency is for all interstitial atoms to return to vacant lattice sites, but judging from experimental data it is clear that this is not a one-stage process. There may be one or more intervening metastable states.

The explanation of the details of the radiation damage in graphite, its effect on the various physical properties of the material and a description of the behaviour on annealing are very obscure, even from a qualitative point of view.

A most important fact is that graphite is full of holes; it has a density of 1·7 grammes per c.c., as opposed to the theoretical figure of 2·27. These holes and the nature of the crystal-to-crystal bond means that the properties of the graphite are not simply related to the properties of the crystals. There exists a very remarkable empirical correlation between the growth of a particular graphite in a given direction and the thermal-expansion coefficient, measured in the same direction. The greater the thermal expansion coefficient, the greater the growth. The annealing temperature, to obtain complete recovery of the crystal lattice spacings and the mechanical growth, is high and the time at the temperature is of some importance.

A lattice containing an interstitial atom, or a vacant lattice site, is in a higher energy state than a perfect lattice. If an interstitial atom migrates to fill a vacant lattice site, some 10 eV of energy appears, as heat. Thus, a piece of graphite which has been damaged by irradiation contains a certain amount of stored energy and if the temperature of the graphite is raised and the irradiation damage annealed, this energy is released. The total stored energy can be measured as the excess of heat liberated on the combustion of irradiated graphite. ("Irradiation Effects on Graphite": Dr. G. B. Greenough, U.K.A.E.A., Industrial Group, Windscale Works, Sellafield, Calderbridge, Cumberland).

Wetting by Liquid Metals

The place of liquid metals in reactor technology is now well established. Three liquid-metal cooled reactors have operated successfully in the United States; they are the Argonne Laboratory's EBR. I, Atomics International's SRE and the Seawolf submarine reactor. In this country the Dounreay fast reactor, which is also liquid-metal cooled, is due to commence operation within the next twelve months. In all these reactors the cooling medium is sodium or the sodium-potassium eutectic alloy which have good heat transfer, nuclear, and electrical properties.

Liquid metals are of interest in the role of combined fuel carrier and cooling medium in liquid-metal fuelled reactors which have the advantages of high-temperature operation and continuous chemical processing. For this purpose the heavy metals bismuth and lead are of primary interest. Liquid metals also pose problems in the nuclear engineering field in a less obvious manner. Both molten metals and molten salts may be employed, separately or together, in the high-temperature chemical processing of fuels for the removal of fission products. In all fields of application of liquid metals wetting problems arise.

When a drop of liquid metal is placed in contact with a solid material it can assume a variety of shapes varying from an almost perfect sphere to a film covering the whole surface. The extent to which spreading occurs depends on the balance of solid and liquid surface tensions or in other words, on the degree to which the solid and liquid interact.

Wetting may be induced by the addition of elements (wetting agents) to the liquid metal. These act in one of two ways. If the addition has a lower surface tension than the bulk liquid it will preferentially adsorb at the surface to give a condition of minimum free energy. The net effect is to lower the liquid surface tension until the conditions for wetting are fulfilled. Alternatively, the addition may not selectively adsorb but may react strongly with the solid to form an intermetallic-compound layer or may reduce surface films.

Once a solid surface is wetted by a liquid metal it is very unusual for de-wetting to occur even if the temperature is lowered. If it does occur it is usually due to contamination or to change of crystal structure in the solid phase.

Finally mention must be made of the role of fluxes in promoting wetting. In many joining operations the liquid metal will not wet the solid even under a reducing atmosphere. It is then necessary to cover both solid and liquid surfaces with a liquid which will promote wetting.

Liquid metals have two great advantages over other cooling media, namely, a high electrical conductivity which permits electromagnetic pumping, and a high thermal conductivity which gives good heat-transfer properties. There has been considerable controversy concerning the importance of wetting in electromagnetic pumps and in heat exchangers. In neither case has it been established that wetting *per se* alters the conductivity values. Where a positive effect has been found it can be traced to surface films or to entrained gas. (" The Wetting of Solids by Liquid Metals," Dr. B. R. T. Frost, Metallurgy Division, A.E.R.E., Harwell.)

Electromagnetic Pumping

Recent developments in nuclear engineering have shown the effectiveness of sodium and the sodium-potassium alloys as intermediate heat-transfer media, and of bismuth as a solvent for uranium in the liquid fuel reactor. The electromagnetic pump, by enabling such liquids to be circulated at high temperatures without glands, seals or moving parts has a great advantage over its mechanical counterpart. (" The Electromagnetic Pumping of Liquid Metals,": Mr. J. A. S. Hilditch, Research Laboratory, British Thomson-Houston Company, Limited, Rugby.)

Mass Transfer

The term " mass transfer " is used to denote processes in which a liquid or vapour takes up a solid at one point by chemical reaction or solution, transfers it by mass flow, convection or diffusion to a point where conditions differ, and there allows it to re-deposit.

A long-known application of mass transfer in technology is the Mond carbonyl process for refining nickel. The de Boer-van Arkel purification of metals is similar. Iodine vapour reacts with a metal to form a volatile iodide which is decomposed at a higher temperature to give pure metal and release the iodine.

Mass transfer similar in type but of importance in reactor engineering is that of carbon in carbon dioxide. Graphite can be taken up by reaction with carbon dioxide to form carbon monoxide and re-deposited at a lower temperature, especially if catalysed by metal surfaces.

An example of mass transfer without a thermal gradient is provided by one process for siliciding metals. Silicon may react with hydrogen chloride to form trichlorosilane ($SiHCl_3$) vapour and at the same temperature this may react with a metal to form a silicide coating.

Much of the present interest in mass transfer arises from consideration of liquid metals in fuels and as heat-transfer media.

Transfer of a material having very low solubility in a liquid metal is possible. Thus, although the solubilities of iron in bismuth are as low as 10 parts per million at 450 deg. C., and 30 parts per million at 550 deg. C., a small loop operated between these temperatures was plugged by iron in 150 hours.

Thermal gradient transfer is a rather complicated process which, in theory, can be divided into a number of stages, any or some of which could be rate-controlling.

Taylor and Ward, at Harwell, have shown that the rate of solution of copper in lead or bismuth, in which solubility is high, occurs rapidly.

Additives of zirconium or titanium made to bismuth have been found to reduce the rate of mass transfer from steels. The mechanism of this inhibition has been studied. A film of stable zirconium nitride has been shown by X-ray diffraction to form at the interface between bismuth and steel, and, presumably, this inhibits reaction between them.

A problem arising from mass transfer is found in the breeder blanket which is a slurry of particles of the thorium bismuth compound, $Th_3\ Bi_5$ in liquid bismuth. Under temperature gradients this slurry is not stable, and the larger particles grow at the expense of smaller ones. They then deposit in cold sections. A possible solution of this problem may be to use, as particles in the slurry, a thorium compound which is insoluble in the liquid metal although wetted by it.

For mass transfer to take place isothermally some attraction is required between two different solids. Thus, nickel heated in lithium in a molybdenum crucible for 1,000 hours at 1,000 deg. C. formed a layer of nickel-molybdenum intermetallic compound on the molybdenum surface. (" Mass Transfer ": Dr. A. K. Covington, Dr. G. A. Geach and Dr. A. A. Woolf, Physical Metallurgy Section, Associated Electrical Industries, Limited, Research Laboratory, Aldermaston, Berkshire.)

Metallurgical Developments

The present design of fuel elements for the Calder Hall reactors uses a natural uranium unalloyed-metal fuel rod of about 1·15 in. in diameter and a magnesium can with transverse fins. The fuel elements of the C.E.A. reactors will operate at surface temperatures of 420 to 450 deg. C. and will have improved heat-transfer surfaces, giving overall average ratings of over 2 MW per ton of uranium—a 50 per cent. improvement on Calder Hall. One of the reactor designs, having a gross electrical output of 360 MW, will contain 500 tons of uranium metal which represents an initial investment of the order of nearly £9 million. This initial fuel investment contributes about £30 per kW to the capital charge of the station, which is more than half the capital cost per kW of conventional stations. This illustrates the great importance of increasing ratings.

Ratings can be increased in two ways: by increasing the surface to volume ratio of the fuel element, and by increasing the temperature of the fuel element surface. A combination of these two developments should increase average ratings to from 5 to 10 MW per ton of uranium. The higher temperatures should also lead to an increase in thermodynamic efficiencies from the 25 to 28 per cent. of the first C.E.A. stations to from 32 to 33 per cent. This also is good for reducing capital and fuel costs.

The fast reactor experiment at Dounreay will use enriched uranium metal fuel elements canned in niobium metal cooled by liquid sodium. Hence, the fast reactor encounters the same problems of irradiation damage, intensified by the higher flux, and, in addition, has to face the corrosion problem associated with the use of high-temperature liquid sodium. The key to this is the reduction of the oxygen content of the sodium to a few parts per million.

The technology of liquid-fuelled reactors using either uranium sulphate in heavy water or uranium in bismuth is also being investigated. The principal problems of these reactors is corrosion in the presence of reactor radiation, and Harwell work is now being concentrated on this. Unless the corrosion and maintenance problems are solved these reactors have no future. If they can be solved, they are likely to be low-cost power producers.

Another important metallurgical problem is the effect of radiation damage on the ductility of the steel used in pressure vessels. It is well known that radiation raises the temperature of the ductile brittle transition. With increased reactor ratings and fluxes, the importance of more knowledge is obvious and tests in existing power reactors and in materials testing reactors are of great importance. (" The Place of Metallurgical Development in the Atomic-Energy Programme ": Sir John Cockcroft, K.C.B., F.R.S., Director, A.E.R.E., Harwell.)

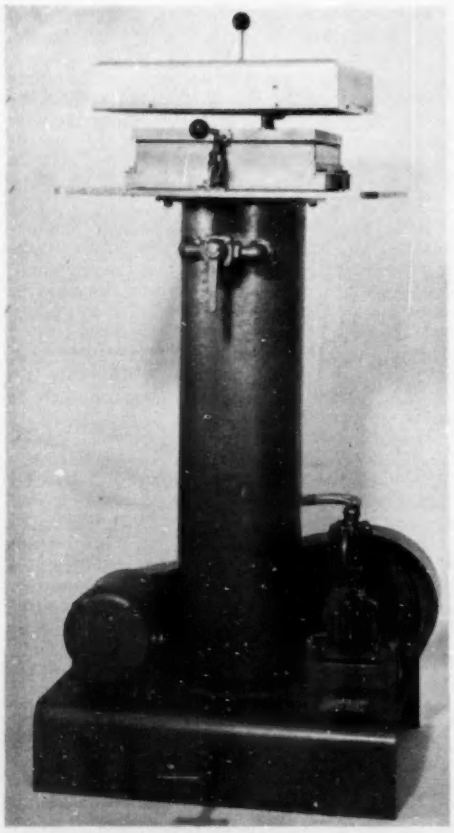
NUCLEAR TANKER

It is significant that several of the men who are directing the design and construction of Britain's first nuclear-powered merchant ship have reached their position of leadership through experience in the look-ahead, long-term aircraft industry. They have acquired the art of planning a project involving innumerable variables and unknowns. This is a vital asset. Aircraft builders have developed it to a high pitch in a few decades, and since the last war the atomic energy pioneers have given us fresh grounds for confidence.

The new company whose formation was announced this week is Hawker Siddeley John Brown Nuclear Construction Limited. Here is a formidable partnership between two groups with ramifications in many engineering fields. The head offices will be in London and the nucleus of the design team consists of men from the Hawker Siddeley Nuclear Power Company, Limited, and from John Brown and Company, Limited. The work of the new company will not be confined to the marine application of atomic energy; Sir Roy Dobson, chairman, envisages " many other interesting nuclear projects."

Mr. Eric Mensforth, a director of John Brown and of the new company, summed up the engineering issues involved in designing the proposed nuclear-powered tanker by saying that " it is a considerable technical adventure . . . there has to be a hunch or an act of faith in a venture of this kind." A tanker has been chosen not only because it is too early for a liner operating company to consider nuclear power seriously, but also because the large capital cost involved will not be lying idle in port so much with a tanker as it would be with a liner; and because a reactor-engined tanker offers the advantage over a conventional tanker that it does not consume part of its own load during a voyage. Apart from the unknown cost of the prototype, the directors of the company are satisfied that nuclear-powered tankers will be able to carry oil more cheaply than present tankers. There is no information yet as to the type of reactor to be used, nor as to the cost or time factors. Preliminary work has been in hand for over a year, so there is no doubt that Britain is well ahead in this important development.

The directors of the new company are: Sir Roy Dobson (chairman), Sir Arnold Hall, Sir William Farren, Mr. E. P. Hawthorn, Sir Stanley Rawson, Mr. Eric Mensforth, Mr. R. J. Barclay, and Mr. V. A. Pask.



Small vacuum forming machine for shaping thermoplastic sheeting. The pedestal constitutes the vacuum reservoir and on top of this is the mould box and electric heater.

SMALL VACUUM FORMING MACHINES

Inexpensive machines for shaping thermoplastic sheeting to a male or female mould by the use of a vacuum, after the sheeting has been brought to a plastic condition by an electric surface heater, have been designed and are being constructed by M. L. Shelley and Partners, Limited, 280 Earls Court-road, Kensington, London, S.W.5.

The machines, one of which is shown in the accompanying illustration, are built of mild-steel plate. Arranged on the base is a ½ h.p. single-phase electric motor driving a vacuum pump supplied by Williams and James (Engineers) Limited, Gloucester. The pump exhausts the pedestal column which forms the vacuum reservoir. On the top of the column is the working surface on which is mounted the mould box. The clamping frame over the box is adjustable and is locked by a toggle clamp, thus permitting different heights of mould box to be used. The electric surface heater is supported by a threaded tube and is adjustable for height.

In operation, the mould (composed of plaster) is put in the mould box and on the top of it is placed a sheet of plastics material which is then clamped by the frame to form an air seal. The heater is swung over the sheet and after a predetermined time, when the sheet has been softened by the heat, the box is exhausted, drawing the plastic sheet over or into the mould. The heater is then swung away, the toggle clamp released and the shaped sheet removed and trimmed.

Two models of the machine, the VF12 and the VF18, are at present available. The first, shown in the illustration, is for forming sheet sizes measuring 12 in. by 12 in. and the second for sheet sizes 18 in. by 18 in. The overall height of each machine is 53 in., and the approximate weight of the smaller machine 280 lb., and of the larger, 300 lb. Both are equipped with a ½ h.p. single-phase motor, but the heater of the VF12 model has a capacity of 2 kW while that of the VF18 machine is 3 kW.

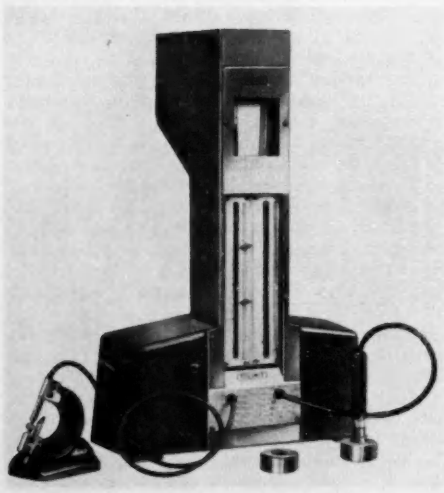
Alternatively, the VF12 machine can be supplied with a spare 18 in. by 18 in. top assembly which, it is stated, is easily interchangeable. Also available are a drape-forming mechanism, for use with male moulds, and a plug-assisted forming mechanism for use with female moulds. The drape-forming mechanism raises the platen and pushes the male mould into the plastic sheet before applying vacuum. This, it is pointed out, gives a thicker-walled component and also enables deeper drawing than is obtainable with plain vacuum forming, and, furthermore, is more economical in material. The plug-assisted forming mechanism pushes the plastic sheet into a female mould by means of a plunger before applying vacuum. Advantages of thicker wall and deeper draw are thus obtained similar to those given by the drape-forming mechanism for male moulds.

★ ★ ★

AUTOMATIC AIR GAUGE

The latest addition to the range of air gauges made by Tolimit Gauges Limited, Peterborough-road, London, S.W.6, is a model which uses a back-pressure balanced air circuit of the manometer type, giving a range of magnifications from 500 to 50,000 to 1. The gauges themselves incorporate high-pressure jets which will clear dirt, grease or coolant from the work or alternatively, the low-pressure type for micro-valve contact with economy of air consumption. Single or multi column units are available. One assembly incorporating two gauges is shown in the illustration below and more may be used for multipoint checking.

To render the equipment automatic, an electronic switching system can be incorporated (or added), which is operated by the position of the liquid in the column of the air gauge. Photo-transistor units can be adjusted behind the columns, so that the light falling on them is cut off as the liquid rises. The induced voltage can be used to operate switching circuits such as are used for machine control, automatic recording or automatic notification or for rejection of the part being gauged. The switching is sensitive to a variation of the height of the liquid in the column of 0·03 in. At a magnification of 5,000 to 1 therefore, the switching accuracy will be within 0·000,006 in. The repetition speed of the photo-transistor is in the range of several hundred cycles per second, since it is cold-cathode working, and its life is practically unlimited. More than one transistor can be used on each column, to indicate the upper and lower limits of the part being checked.

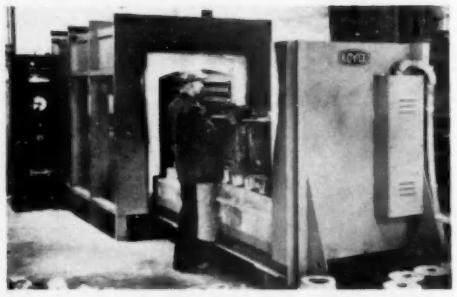


The use of photo-transistors renders air gauging fully automatic.

BOGIE-HEARTH ELECTRIC ANNEALING FURNACE

An electric resistance furnace of the bogie-hearth type for annealing spheroidal-graphite iron and other castings has been developed by Royce Electric Furnaces Limited, Sir Richard's Bridge, Walton-on-Thames, Surrey. The furnace is shown in the accompanying illustration, from which it will be noted that the bogie and the door are manufactured as a complete unit; this unit can be pushed into the furnace by hand, when fully loaded, and an effective heat seal between the bogie and the furnace casing secured.

The maximum temperature attainable is 1,000 deg. C., and the rating of the furnace is 75 kW. The overall dimensions are approximately 7 ft. 6 in. wide by 7 ft. 8 in. high by 10 ft. 2 in. long, to which must be added an 8 ft. rail extension for drawing out the bogie. The usable chamber dimensions are 2 ft. 6 in. wide by 2 ft. 6 in. high by 6 ft. long. The furnace casing is built up of heavy-gauge mild-steel sheet reinforced with channel and angle sections of welded construction; bolted construction may be employed if preferred. The bogie consists of a grillage built up of rolled-steel members, plate, and angle supported flanges, mounted on cast-iron wheels running on light bridge rails. The hearth comprises sillimanite



Bogie-hearth furnace heated by nickel-chromium elements in which the bogie and the door are built as one unit. The rating of the furnace is 75 kW and the maximum temperature attainable is 1,000 deg. C. It is used for annealing castings.

cross pieces supported on piers allowing the free radiation of heat and the circulation of air. The furnace chamber is lined throughout with high-quality refractory backed by insulating material, thus giving efficient thermal insulation. The heating elements consist of heavy-section 80 : 20 nickel-chromium alloy arranged in T tiles in the side walls, roof and door. The elements are designed for easy removal and replacement. Lead-outs of increased cross section are provided within the ventilated terminal boxes.

Fully-automatic temperature-control gear is included and a programme controller can be incorporated to give a regulated heating and cooling cycle, as may be necessary, for instance, for the heat treatment of spheroidal-graphite iron castings. A typical cycle would include a heating-up time of about 4½ hours, which would bring the temperature up to 900 deg. C. A soaking time of from 4 to 6 hours, at 900 deg. C., would then be allowed and this would be followed by a forced cooling time of two hours during which the temperature would be reduced to 750 deg. C. The fourth stage of the cycle would consist of controlled slow cooling for ten hours at a rate of fall of not more than 10 deg. C. per hour. On reaching 650 deg. C. the charge would be withdrawn. The forced cooling referred to above is realised by blowing air through heat-resisting steel distributing pipes inside the furnace chamber. Alternatively, cooling may be assisted by the simple process of opening the door.

In addition to the 75 kW furnace described above, a number of other standard sizes are available, ranging from 50 kW to 93 kW, with proportionate dimensions. Non-standard units, heated by electricity or gas and with capacities of up to 20,000 cub. ft., are also manufactured.

In Parliament

WATER CONSERVATION AND IRRIGATION PROBLEMS

In the House of Lords last week, a brief debate was initiated by Lord Albemarle (Conservative) on water economics. He called upon the Government to declare what surface-water conservation policy they inclined to, so that applicants for permission to extract irrigation water throughout the drier coast counties might be assisted in their efforts to step up food production. In particular, he wondered whether it might be helpful if the Government made orders for the construction of weirs in rivers where dry weather resulted in an insufficient depth of water, thereby precluding irrigation.

Lord Alexander of Hillsborough (Labour) felt that, next to water for household consumption, preference should be given to agriculture. Water for new industrial planning developments should come after these needs had been satisfied. Lord Lucas of Chilworth (Labour) thought that, as far as householders were concerned, it was not so much the shortage of water as the lack of a system for supplying it that caused the trouble.

Replying for the Government, Lord Mancroft, Minister without Portfolio, said that the loss of agricultural land for building and other development in England and Wales had averaged 37,000 acres per annum during recent years. Irrigation could have a beneficial effect at selected times and places on agricultural production and should not be discouraged, provided that demands for water for that purpose were not incompatible with other local requirements. A sub-committee of the Central Advisory Water Committee was at present inquiring into demands for water for all purposes, how these needs were increasing, and the problems involved in meeting them. The inquiry was more comprehensive than any previously undertaken and the Government preferred to await the outcome.

CIVIL ENGINEERING CONTRACTS

Replying to a question by Mr. Graham Page (Conservative) regarding the extent to which the Government's decision to invite tenders for building and civil-engineering work on a fixed-price basis, that is to say without the inclusion of cost variation clauses for labour and materials, Mr. Hugh Molson, the Minister of Works, referred to an answer he gave in the House on April 30. He stated then that the Government had decided that all ministries should invite tenders on that basis for all works of a building or civil-engineering nature, irrespective of size, provided that they had been thoroughly planned in advance and that the estimated contract period was not more than two years. Local authorities and the nationalised industries had been invited to adopt a similar policy.

Mr. Molson added that the ministries concerned had made arrangements for fixed-price tenders to be invited for suitable jobs as they reached the appropriate stage of full planning. The results in the Ministry of Works during a year's experimental period had proved very satisfactory.

TECHNOLOGY TEACHERS' SALARIES

The dissatisfaction which is stated to exist in respect to the salary scales now proposed for Scottish technical colleges was brought to the notice of the Secretary of State for Scotland by Mr. Hector Hughes (Labour). This action produced a statement from Mr. John Maclay to the effect that the governing bodies of Robert Gordon's Technical College, Aberdeen; Dundee Technical College; the Heriot-Watt College, Edinburgh; and Paisley Technical College, after considering the recommendations of their staff associations, made proposals for new salary scales to the associations in April. These proposals were accepted by the staff of the Heriot-Watt College. The staff associations of the remaining three colleges, however, did not regard the proposals as acceptable and the Secretary of State, Mr. Maclay, had carefully considered their criticisms. He was not satisfied that the changes that had been suggested were justified, but he was inviting the governing bodies concerned to discuss the matter with officials of the Scottish Office.

With respect to a suggestion by Mr. Hughes that the joint consultation machinery between the relevant staff associations and their governors was "unsatisfactory and ineffective," Mr. Maclay told the House that representatives of the governing bodies and the staff associations met the industrial relations officer of the Ministry of Labour on July 2, to consider the possibility of setting up joint machinery to negotiate salary scales, before these were submitted for his approval. Two of the governing bodies and three of the staff associations indicated their willingness to participate in such machinery. The representatives of the remaining two governing bodies and one staff association undertook to have the proposal considered further by the bodies they represented. The Minister hoped that the outcome of these various talks would be the establishment of satisfactory negotiating machinery.

EXPLOITING EMPIRE MINERALS

Attention was drawn by Mr. Robert Edwards (Labour-Co-operative) to the discussions which have taken place between the Governments of the United Kingdom and Sierra Leone regarding the desire of the Columbia-Southern Chemicals Company and British Titan Products Limited to develop rutile deposits in Sierra Leone. He asked the Secretary of State for the Colonies to take into consideration that, in spite of its name, British Titan Products was really an international firm and "part of an international restrictive cartel." He desired an assurance that what had happened in pre-war days should not be repeated and that, if the company received permission to develop, it should really do so and not restrict developments in order to restrict some other firm exploiting these important deposits.

Mr. John Profumo, the Under-Secretary of State for the Colonies, said that negotiations broke down because the authorities were unable "to grant various things which the company wanted." It would be better to wait until negotiations were re-opened before going into the matter any further.

ROYAL NAVAL ENGINEERING COLLEGE

A statement from Mr. Christopher Soames, the Parliamentary and Financial Secretary to the Admiralty, respecting the future of H.M.S. Thunderer, the Royal Naval Engineering College, was asked for by Mr. A. G. Bottomley (Labour). He thought that the new site for the College was one that would not permit of any future expansion of the College that might be necessary, and inquired why the long-neglected site of the Royal Marine Barracks at Chatham had not been considered. In reply, Mr. Soames said that, on the completion of the present building programme at Manadon, the Royal Navy would possess a fully equipped engineering university, able to accommodate some 350 officers. Training would continue as at present in basic engineering subjects, and in advanced marine, ordnance and aeronautical engineering. Current developments in nuclear engineering would also be included in the curriculum. The site at Manadon had been chosen in 1939, but building had been delayed owing to the war. The Royal Naval Engineering College had always been near Devonport. Previously, it has been at Keyham. The Board of Admiralty believed that the site selected would fulfil all their requirements.

INTERRUPTIONS IN ELECTRICITY SUPPLY

Some pressure was brought to bear on the Paymaster-General to give a general direction to the Central Electricity Authority to provide alternative supplies of electricity to all areas, so that all current might not be cut off when severe storms arose. Dr. Somerville Hastings (Labour) pointed out that a part of South Oxfordshire was without electricity for two and a half hours on June 30. Wing-Commander R. G. Grant-Ferris (Conservative) urged the cause of those parts of the country that had no electricity at all, and Mr. Alfred Robens (Labour) referred to the plight of hospitals when electricity supplies failed. Mr. Reginald Maudling said he was unable to give such a direction. The electricity authorities were spending large sums already in safeguarding supplies during emergencies. The cost of attempting to safeguard against all risks would be prohibitive.

Domestic Electrical Appliances

The Home Secretary was urged by Dr. Somerville Hastings to introduce legislation which would ensure the annual inspection of all hired electrical equipment, in view of the 55 deaths which had occurred, as a result of electrocution in the home in 1956. This, Mr. R. A. Butler declined to do. According to his information few accidents were caused by faulty electrical appliances. Hired appliances were regularly maintained by their owners.

Nuclear Energy Aero Engines

It transpired from an answer given by Mr. W. J. Taylor, the Parliamentary Secretary to the Ministry of Supply, to Mr. Paul Williams (Independent Conservative) that the Ministry of Supply is now engaged on preliminary research work on the application of atomic power to aero engines. No further information, however, appears to be available.

More Steel for Ships

Supplies of steel for use in British shipyards are improving. Mr. T. G. D. Galbraith, Civil Lord of the Admiralty, informed Mr. Paul Williams (Independent Conservative) that the shipbuilding industry had received about 5 per cent. more steel this year than during the corresponding period in 1956. The percentage increases for individual months were a good deal higher than that, except in the case of March and April when conditions were abnormal owing to the strike in the shipbuilding industry.

Good Year for Launchings

In answer to other points raised by Mr. Paul Williams, the House was informed by Mr. Galbraith that no fewer than 131 merchant ships, having a total capacity of about 619,500 tons gross, were launched at shipyards in the United Kingdom during the first six months of this year. Launchings from shipyards on the North-East Coast numbered 36, and the total capacity of these vessels amounted to about 291,000 tons gross.

South Wales Port Improvements

Mr. James Callaghan (Labour) asked the Minister of Transport and Civil Aviation whether it was with his agreement, in accordance with Section 4 (2) of the Transport Act, 1947, that the port of Cardiff was excluded from the plans of the British Transport Commission for improvements at the South Wales ports. Mr. Harold Watkinson said that the decision was taken by the Commission itself, although its chairman did, in fact, inform him of what was proposed.

Sewage Disposal Schemes

Mr. Henry Brooke, the Minister of Housing and Local Government, told Mr. James Johnson (Labour) that, since January 1, 1955, no fewer than 52 inland county boroughs, apart from Coventry, had had works of sewerage or sewage disposal authorised whereby there should be improvements in the effluent discharged into rivers in the vicinity. The cost of these schemes amounted to £11,600,000. Since the passing of the Rivers (Prevention of Pollution) Act, 1951, reports had been received from 16 river boards of improvements in the condition of their rivers.

RESEARCH OPENINGS

Summer is the open season for opening days. And with the value of research receiving growing emphasis, it is not surprising that several new research centres have been opened recently. This article deals with three: the laboratories of a research association, a private firm, and a university. They are located well apart in England. Each has its own character and personal history. All have in common an atmosphere in which a lively and critical attitude flourishes.

E.R.A. LABORATORY

A wide programme of research exists at the new laboratories of the Electrical Research Association at Leatherhead. Problems of immediate interest to industry are studied and fundamental investigations also are carried out. There is a staff of about 330.

The development of an oxide film capacitor is an example of work done with a practical end in view. In this capacitor an oxide film, formed by anodising, separates two layers of aluminium. High purity aluminium foil, upon which the anodising process is carried out, forms the starting point for manufacture. One limitation to the process is that it is very difficult to get high purity foil that is less than 0·0005 in. thick. The second layer of aluminium is deposited on the oxide film by vacuum evaporation.

A feature of the capacitor is that the oxide film is self healing. If it gets punctured the local increase in current density causes the thin evaporated electrode to burn. When this happens the two conducting layers become once more separated. The capacitor is suitable for use over a wide temperature range (— 180 to + 120 deg.C.).

It is usual to wind the thin sandwich on to a circular former. With oxide film thicknesses of about 1 micron, the former must have a diameter greater than 9 mm., otherwise cracks occur in the film. Such a capacitor could work at about 200 volts d.c. and its capacity can be made quite large with very little increase of the basic dimensions.

An example of fundamental research is provided by some of the work in the crystal physics laboratory. Some ferro-electric materials are being studied there. Ferro-electrics are the electrical analogue of ferro-magnetic materials. In particular they show a hysteresis loop similar to that of iron, but for electrical instead of magnetic co-ordinates. At Leatherhead mixed sodium potassium niobate crystals are being studied. This and similar materials were chosen because of the relative ease with which the composition can be varied. A typical formula for a material under investigation would be $(Na_{.995}\ K_{.005})NbO_3$. Such materials can exist in both ferro and antiferro-electric states and are interesting in that they exhibit double hysteresis loops.

Among other researches being carried out is the work on the network analyser shown in the illustration. The analyser is made up of a large number of components that can be connected up to simulate various practical situations notably power supply systems. It operates, around a frequency of 1,592 c.p.s.—a frequency variation of 100 : 1 being possible. With the equipment the effects of faults on real power supply systems can be studied. Such experiments can be made at potentials that do not exceed a few volts. It is also possible to undertake studies of heat flow and mechanical vibration problems.

Other work at the laboratories is concerned with cables, transformers, lightning, heating, insulators, transmission problems, radio interference, safety, creep in steel, and electric arcs. Work in the last subject has shown that the temperatures in arcs can be very much higher than had previously been thought possible. Under special conditions temperatures can reach 50,000 deg. K.

The heating of the various buildings has been designed bearing in mind the improvement of the load factor achieved by a night-heating load. The main building is heated by conventional radiators. The water used is heated between 9 p.m. and 7 a.m. by electric immersion heaters fitted into six highly insulated hot water storage vessels. Each vessel holds about 3,000 gallons of water and is loaded to 126 kW.

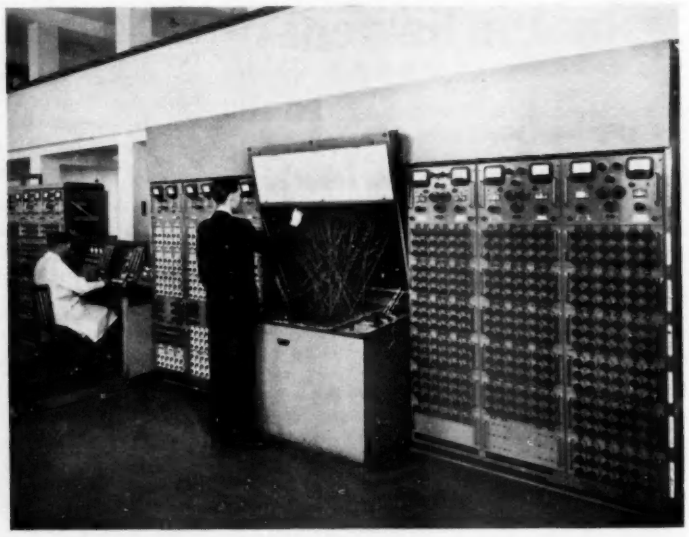
Floor heating has been chosen for the high-voltage building because the staff usually works in the lower part of the hall, which is 50 ft. high. The heating is by electrical conductors threaded into ducts embedded in the concrete floor slab. The whole of the workshop building, excluding the canteen, is heated the same way. In the canteen, thermal storage heaters are used. This last installation is used for the investigation of methods of control, taking into account the off-peak supply conditions and the short periods of daily use.

All of the new buildings are of steel frame and brickwork construction. The main building has three main floors and a mezzanine floor. It is made up of a central section with two main wings on the same elevation and a third wing at the rear of the central section on the west elevation. The ground, second and third floors of the central section and its north and south wings are of normal height while a large part of the first floor has a ceiling height of 18 ft., the remainder being covered by a mezzanine floor. Space is thus provided on the first floor for work requiring greater headroom and, at the same time, the mezzanine floor provides additional working space and an observation platform. In the west wing the three floors are of normal height.

The north and south wings provide space for twelve standard laboratories—each 50 ft. by 35 ft. There are three similar units in the west wing, giving a total of 15 laboratories excluding accommodation on the mezzanine floor.

The high-voltage building has a central high-voltage hall with a floor area of 100 ft. by 50 ft. and a height of 50 ft. A 2·8 megavolt surge generator is installed that is particularly suitable for surge tests on very high voltage transmission equipment requiring a high energy input.

The laboratories were opened by Lord Mills who spoke of the need for research and the importance of the electrical industry.



This versatile network analyser is under construction at the E.R.A. laboratories recently opened at Leatherhead. When complete, it will be one of the largest in the world.

SOAP LABORATORY

The new laboratories of Thomas Hedley and Company, Limited, at Longbenton, Newcastle-upon-Tyne, house the departments doing product research and development work on both washing products and edible products. They were opened by His Grace the Duke of Northumberland. Here the research is very practical and there is a constant interchange between the laboratories, the main factory, and the market research department.

To study washing problems as they appear to the housewife, a home laundry is installed. This does the washing of 75 of the firm's families and studies the effects of different methods. To simulate home conditions the types of washing equipment used are in the proportions that exist throughout the country. It is found that out of every 10 housewives, 3 have an electric washing machine, one a hand-operated machine, and the remainder wash by hand.

The new fluorescers that increase whiteness are an important subject of study. These materials, which must be attached to the fabric, absorb ultra-violet light from the sun's rays and emit blue light. When the blue light combines with the slightly yellow light of the "white" fabric a true white light is produced.

For fluorescers to attach themselves to fabric they must have a molecular structure that will key on to fibre molecules. A main feature of present fluorescers is the presence of hydrogen bonds situated 10·8 Å apart. If such a molecule can be dissolved in water it can be made to stick on to cotton—which has atoms spaced at intervals corresponding to those of the fluorescer. It is worth noting the very different conditions that hold for such operations as compared with those of dyeing. Usually dyes are put into a fabric under acid conditions at high concentrations and often high pressures and temperatures. The housewife does the weekly wash under very different conditions. The fluorescers do not stick easily to wool or nylon because of their different molecular configuration.

One of the problems in developing fluorescers is that they are destroyed by sunlight. It is necessary to ensure that the broken-up molecules are not coloured. Effective bleaches attack fluorescers and so those not readily stripped from the fabric by chlorine must be chosen.

Other activities at Longbenton include pilot plants, for development of detergent granules, soap and edible products; a research bakery; packaging research; and a laboratory devoted to testing the effects of the products on the skin.

The building is designed in two main blocks on an east-west axis with a connecting north-south block. With the exception of the rear east-west block, the building is single storey. The front east-west block is 330 ft. long by 50 ft. wide. The floor is of concrete and the walls are of load-bearing brick. The roof is formed of hollow block insulated and covered with asphalt. The whole block has been designed and built in units about 50 ft. square, with flexible joints so that should uneven settlement take place due to colliery workings, movement in the structure can be controlled.

The rear block is planned to house the pilot plant and is a steel-framed building 180 ft. long by 75 ft. wide. Inside the building a mezzanine floor extends for the whole width and approximately two-thirds the length, leaving a high-level area rising to the full height of the building,

which is 26 ft. from ground level to the underside of the roof trusses.

UNIVERSITY LABORATORY

The new extensions to the electrical engineering department at the University of Sheffield were opened by Sir Harold Bishop. A new engineering building was completed in 1954 and houses most of the laboratories of the departments of civil and mechanical engineering. The space previously occupied by these two departments has been used for the new extensions to the department of electrical engineering.

In his speech, Sir Harold referred to the high percentage of students that fail the examination at the end of the first year of study: the figure quoted for Sheffield was 30 per cent. Using the phrase " sixth forms are merely guided missiles directed at the university," Sir Harold suggested that there should be a broader basis for acceptance to a university. In his opinion, future scientists and engineers should spend 40 per cent. of their time, prior to entry to a university, studying arts subjects. He added that future arts men should spend 40 per cent. of their time studying science. The university should take over the burden of teaching subjects that are not so easily taught in schools.

Sir Harold suggested that it might be worth while, if the present three-year course cannot be extended, for most students to study for three years to obtain an ordinary degree, while a few stop on for an extra year to get an honours degree. However, he pointed out that the engineering profession would be making a grave mistake if it neglected to consider the need for a supply of technicians. Four technicians are required for every qualified engineer.

The expansion of the facilities at the electrical engineering department has enabled a much larger number of students to be accepted. The chief difficulty at the moment is to find sufficient lecturers. The department now has double the floor space, and accommodation includes ten laboratories. These are divided between undergraduates and research workers. Research at present falls into four main categories: microwaves, voltage stabilisation, electrical machinery, and properties of materials. In the first category, three researches are being made into various aspects of electromagnetic surface waves. One of the experiments is the measurement of the electrical properties of glass at a wavelength of 8 mm. A dipole-mode surface wave on a glass rod waveguide is used for this.

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CANADIAN PACIFIC LINER

Negotiations have been completed between Canadian Pacific Steamships, Limited, Montreal, and Vickers-Armstrongs, Limited, London, for the construction by the latter of a new liner, to carry approximately 200 first-class and 875 tourist-class passengers. She will be designed for the North Atlantic service in the St. Lawrence summer season and for cruising in the winter, and will be commissioned in the spring of 1961. The vessel will be constructed at the Naval Yard, Walker-on-Tyne, and the machinery at Barrow-in-Furness.

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NOTICES OF MEETINGS

Institution of Mining Engineers

NEWCASTLE-UPON-TYNE
Summer Meeting, Wed., July 24, to Fri., July 26. " Colliery Reconstruction in North Staffordshire," by R. W. Scurfield, at 11 a.m.; and " Off-Shore Boring," by F. Marsh, G. Armstrong and W. S. Drysdale, at 2.30 p.m. Hall of the Literary and Philosophical Society, Westgate-road, Newcastle-upon-Tyne. Wed., July 24.

Plastics Institute

LONDON
Annual General Meeting. Gallery Conference Room, National Hall, Olympia, W.14. Fri., July 19, 12 noon.

The addresses and telephone numbers of the headquarters of the above institutions are given below.

Institution of Mining Engineers, 3 Grosvenor-crescent, London, S.W.1. (BELgravia 3691.)
Plastics Institute, 6 Mandeville-place, London, W.1. (WELbeck 5439.)

Fiat 500—first miniature car from a major manufacturer. Designed for production of 800 a day in the greatly extended Turin works.

FIAT 500

The great new Mirafiori Sud factory of Fiat at Turin is rapidly approaching completion (although work only began in April last year) and already part of it is in operation, on production of the new Fiat 500, first miniature economy car built by a major manufacturer.

Designed to create a new class of car owners among people who have previously used scooters, the 500 follows the design principles enunciated by Dott. Ing. Dante Giacosa, director of vehicle engineering at Fiat, in his James Clayton Lecture to the Institution of Mechanical Engineers in March this year. It is a true small car with high qualities of steering, road holding and braking, and sufficient strength of suspension and structure for use on mountain roads as well as city streets. It has only two seats, but behind them is a seat-shaped structure which can carry two children or a good quantity of luggage, and the accessory manufacturers will probably lose no time in producing cushions for the rear section. Nothing has been skimped in the mechanical specification. It has independent suspension to all four wheels very similar to that of the Fiat 600, and self-adjusting hydraulic brakes on all four wheels. The air-cooled vertical twin engine is at the rear in unit with a four-speed gearbox. Only one model is being made, a saloon with folding top. The main departure from previous Fiat practice lies in the use of an air-cooled engine. It shows a cost advantage, and it was felt that the technique of silencing without excessive weight penalty now permits its use without sacrifice of the important impression of quality.

In fact Dott. Giacosa envisages its extension to larger cars in the future. The low compression ratio of 6·55 to 1 permits use of low-grade fuels, and with an output of 13 b.h.p. at 4,000 r.p.m. from 479 c.c. the engine is not highly stressed.

The cooling system is highly developed. A centrifugal impeller on the end of the dynamo draws air from a labyrinth below the rear window, where water is trapped, and sends part of it across cylinders and head. Part is bled off to pass through a filter to the carburetter, and part goes through cooling passages in the surface of the sump. A thermostat operates a flap valve to permit re-circulation of warm air for rapid warming up in winter, and warm air can also be supplied to the car interior.

Light-alloy die castings are used for crankcase and gearbox. The finned cylinders are an iron casting, and the two heads are a single light-alloy casting with inserted valve seats. The two-bearing crankshaft is also cast iron. An interesting detail is the use of the fan pulley as a centrifugal oil filter.

But the outstanding achievement is the engine mounting, which so effectively suppresses the vibrations of the vertical twin that it is impossible to tell that the engine is not a four-cylinder, even when idling, or pulling hard in top from low speeds. Vertical motion of the engine is controlled by a flexible coil spring, while torsional vibrations are controlled by a broad horizontal link, pivoting on two rubber bushes on the engine and two on the frame. The engine is thus free to move through a considerable amplitude vertically, but is more closely restrained in torsion. The front mounting, under the gearbox, is by rubber cushions in V-formation.

In appearance the car is a scaled-down 600, with wheelbase reduced by 2¾ in. and track about an inch smaller. Weight is about 105 lb. less. The seats have light fabric pads on rubber bands stretched over a tubular frame and the doors have fixed windows, with hinged ventilating panels. There are two controllable fresh air intakes at the front of the car, and in warm weather the whole top of the car can be folded back.

The use of a four-speed gearbox without synchromesh would appear to be founded upon a high level of driving skill among the Italians, but in practice, changes into the constant-mesh second, third and top are very easy, even without double de-clutching.

At present, Fiat output is about 1,200 cars a day, including 700 of the Fiat 600. The new model is expected to lift the total daily output to 2,000 units. The plant is being reorganised, and some advanced ideas on automatic machining and handling of materials are being introduced. The new factory, Mirafiori Sud, is connected to the existing one by a vast system of underground roadways, and galleries, totalling 5½ miles. This not only permits free circulation under the main road which separates the two; it also houses conveyors taking sheet steel to the press shop which will be concentrated in the new building, and carrying pressings from the press shop to the assembly lines in the older building. In addition, it is to be used as a weather-proof store for raw materials and finished cars.

The main details of the new 500 are :

Engine. Vertical twin four-stroke, o.h.v., air cooled. 66 × 70 mm. 479 cc. Compression ratio 6·55 to 1. 13 b.h.p. at 4,000 r.p.m.

Transmission. Single-plate dry clutch. Four-speed constant-mesh gearbox. Gearbox ratios 3·273, 2·067, 1·300, 0·875 to 1. Reverse 4·134 to 1. Final bevel drive 5·125 to 1.

Suspension and Steering. Independent front, by wishbones and a transverse leaf spring shackled at two points to increase roll stiffness. Independent rear by single wishbones and coil springs. Worm and sector steering with three-piece linkage.

Speeds in gears. 1st 16 m.p.h., 2nd 25 m.p.h., 3rd 38 m.p.h., 4th 55–60 m.p.h.

Fuel consumption. 63 m.p.g. approx.

Dimensions. Wheelbase 72·4 in. Track front 44·1 in. Track rear 44·7 in. Length 116 in., width 52 in., height unladen 52·2 in. Kerb weight 1,036 lb.

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BULK DELIVERY

Designed for the delivery of animal feeding stuffs, a wagon has been developed which can handle either bagged or loose loads. The vehicle is based on a B.M.C. 7 ton long wheelbase chassis, and the body was built by Boalloy of Congleton.

A bulkhead is fitted in the vehicle, which provides two separate compartments, and at the rear is a hopper, into which sacks can be emptied, and their contents conveyed pneumatically by pipeline to storage bins. The body is also fitted with a hydraulic tipping mechanism.

THE HUMAN ELEMENT

New Skills for the Future

A strong plea for a more objective study of human behaviour at work and for the use of a scientific approach to training problems was put forward in a paper presented to the Institution of Production Engineers at their recent conference at Harrogate. "What New Skills will the Future Demand?" by Mr. C. B. Gibbs, is a brief review of the advances that have been made in applied psychology and of the fields in which the new techniques could most usefully be applied. Behaviour studies, which are the main source of knowledge on which a scientific approach to training can be based, are still very limited in their scope. As Mr. Gibbs points out, "we have now more respect for science and verified fact, but prejudice and tradition can still obscure those facts relating to human behaviour."

One field in which behaviour studies have a vital part to play is in the design of machines. Mr. Gibbs quotes the case of a new, complex and expensive machine which demanded rapid and skilful action at one part of the cycle of operations. Tests were made with a number of operators of a wide range of ability, and the precise nature of the training required was determined. In this case much time and expense were saved by making the tests, which pointed to important modifications and improvements of the original idea. Another application is in counteracting what Mr. Gibbs calls "the blinding effect of habit and custom."

The problem is to design machines "so that the habitual skills of everyday life show the highest possible transfer to their use." This will reduce learning time, increase the number of people who can learn and reduce the risk of accidents when operators are under stress. The teaching skills, now the subject of much advanced research, could be considerably improved and the time taken to learn reduced to a fraction of present needs.

Worth of a Sleeping Watchdog

The Court of Appeal has ruled that it is absurd that a man should earn both overtime and special time while he is asleep. Lesser mortals will find in such a pronouncement common sense as well as good law. A retired night watchman had appealed against the dismissal of his claim in a lower court for £2,051 arrears of wages from his former employers, a catering establishment.

The plaintiff was paid £7 3*s*. a week from 1949 until he retired. It was said that he did a 93-hour week although he was required to do only three active hours work each night. He claimed that he was entitled to sleeping time as he was paid as a sleeping watchdog. His former employers stated that he slept for 63 hours and that his pay was above the rate for a 47-hour week. The Court of Appeal found that he had no case under the Catering Wages Act of 1943.

Such instances show how narrow a line separates sense from nonsense. Once allow that a man may be paid for being a sleeping watchman, then he can be paid overtime for going home early and draw a wage for contracting not to turn up. This sort of thing has happened before. In the depression, farmers in America were paid for not raising pigs and not growing wheat. There is, however, a time when common sense takes precedence over economics—even in times of full employment.

Salaries in Nationalised Industry

The recent announcement of substantial increases in the salaries of the members of the boards of nationalised industries will be the subject of a White Paper. This will show how the salary increases will extend right through to regional boards and may become the official blue-print for the revision of the salaries of those—in nationalised industries and elsewhere—who earn between £1500 and £3500 a year.

It is in these ranges that the greatest difficulty is experienced in recruiting men of the right calibre, and also the sector in which the lowest net increase in purchasing power has taken place since the war. How far the salary increases will be reflected throughout the nationalised industries is not yet clear, but a general increase is likely in the higher grades. The raising of board salaries is the first step, since these tend to act as a ceiling for those which can be offered to managerial and technical staffs. The report of the Herbert Committee on the electricity supply industry drew attention to this problem and recommended the raising of the salaries of board members with the question of differentials very much in mind.

The Government's policy would appear to be an improvement in the financial status of people in positions of responsibility, in Parliament, nationalised industries and the civil service. Their rewards have grown far less than those of their subordinates and the time may well have come when they are too pre-occupied with financial worries to give of their best.

Liability for National Service

As national service is coming to an end it is likely in the circumstances that umpires dealing with hardship cases will be under increasing pressure to give decisions in favour of applicants. There is nothing logical about this. In a sense, the nearer national service comes to its demise the more valuable will the remaining recruits become. But institutions rarely work that way. Children do not study harder at school in the last weeks before the summer holidays because they ought to try and cram in as much as possible before they go away and so ensure that the tax-payer or fee-paying parent gets full value for money. They work less hard because it is all coming to an end. So it will be with national service.

Several decisions have been handed down by umpires in the latest Ministry of Labour and National Service pamphlet dealing with the National Service Acts 1948-1955 (N.S. Code 2, Pamphlet 2/57). A number of opinions have been given on the postponement or exemption from national service for men with dependent mothers. They relate mainly to circumstances where the mother's health may constitute a case for special treatment of the man. The circumstances extend to where the mother's health makes it impossible for her to carry on a smallholding alone.

Vacancies Increase

Last month, for the first time since December, 1946, there were fewer unemployed than vacancies in British industry. The number of unfilled vacancies was 309,000; 26,000 more than in May. Unemployed numbered 265,000, a drop of 49,000 in the month. The ratio of unemployed to total working population in June was 1·2 per cent., compared with 1·5 per cent. in May, but 1·0 per cent. a year ago.

This picture of a sharply expanding economy is confirmed by the news that overtime is on the increase and short time on the decrease. The economy has not, however, returned fully to the very tight labour position of a year ago. The 1½ million people on overtime in the last week in May were still 30,000 less than in May, 1956, and total numbers in civil employment were 100,000 less than last year's peak of 23 million.

The detailed changes in the labour position suggest that higher consumer expenditure is mainly responsible for the new boom. The labour force in manufacturing industry actually declined by 1,000 in May, but the numbers employed in agriculture and transport increased by 10,000 and those employed in distributive and service trades by 14,000. In manufacturing industry there was a net switch of workers away from engineering, textiles and chemicals to the food drink, and tobacco industries. All this suggests that food consumption is leading the sharp burst of expansion now taking place. Engineering, so far, has lagged behind, with the exception of vehicles and domestic appliances.

Siberia—Modern Version

In Nineteenth Century folklore the salt mines of Siberia played a sinister, nightmare role in contrast to the romantic wild and woolly West. Here was a prison, not of confinement, so much as of sheer expansiveness. These tundras and wastelands had a hopelessness of their own for reformers, radicals, nihilists and, later, communists. It was so until almost yesterday. With the new appointment of Mr. Malenkov a more sophisticated version of banishment to Asia has been discovered.

For Malenkov there is the banishment and the degradation of a more subtle sort. He goes as Trotsky went but here too there is a difference. In the world of to-day no one is to be unoccupied. Malenkov is given a job. He is to be sent far away from anywhere within the Soviet hierarchy where he can make mischief, but his abilities, his brainpower, is still exploited. He is too useful a cog in the machine to push salt wagons or make mailbags. He is given the useful but humiliating job of running a power station under local bureaucrats who once trembled at his anger. This is the new, the humane, the cultured form of banishment. But after all the Nineteenth Century would have understood it—or at least those who had heard of Gilbert and Sullivan's Mikado would have done. Even in the 1870's there was comedy in the thought of making the punishment fit the crime.

Clyde to Seine

A welcome addition to the facilities for railway travel from this country to the Continent, was the "Caledonian" express between Euston and Glasgow, which was introduced with the summer timetable. It is timed to do the 401 mile journey in 400 minutes. More important than this, however, is the fact that since it leaves Glasgow at 8.30 in the morning, and arrives at Euston at 3.10 in the afternoon, passengers bound for the Continent have just time to join the 4.30 p.m. train from Victoria, also a summer service, which completes the journey to Paris in the same day. Similarly, on the return, travellers can leave Paris by the 7.6 morning train, arrive in London at 2.06 p.m. and catch the 4.15 p.m. Caledonian from Euston, which arrives in Glasgow at 10.55 p.m. Once again, the complete journey is carried out in less than 24 hours. The 4.30 train from Victoria also connects with other express trains on the Continent to such places as Basle.

Whether by accident or design, this connecting running of trains, enabling passengers from the North to pass through London and reach the South without undue delay, is certainly a step very much in the right direction. If such a state of affairs can be accomplished allowing for all the vagaries of the English Channel, it leads to great hopes for similar through services, possibly even without the painful necessity of a change in London, if the Channel tunnel is completed.

ENGINEERING

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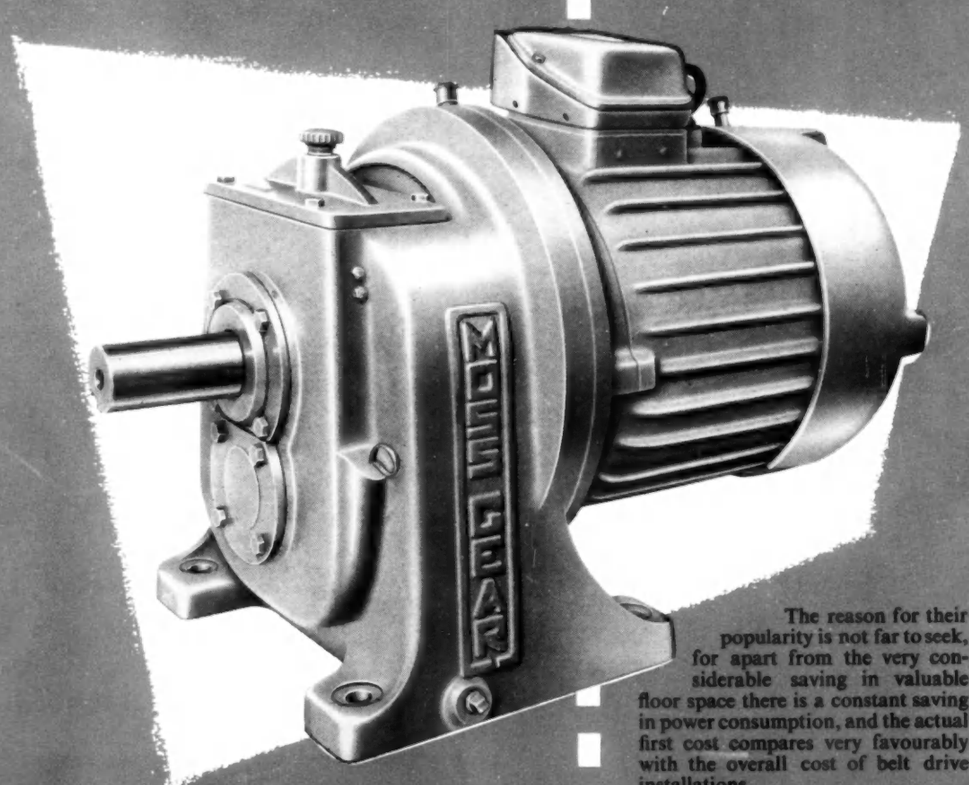

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